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NATIONAL
Electric Light
ASSOCIATION.

TWENTY-FIRST CONVENTION.

CHICAGO, ILL.,
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CONVENTIONS OF THE ASSOCIATION

First	Chicago, February 25, 26, 1885
Second	New York, August 18, 19, 20, 1885
Third	Baltimore, February 10, 11, 12, 1886
Fourth	Detroit, August 31, September 1, 2, 1886
Fifth	Philadelphia, February 15, 16, 17, 1887
Sixth	Boston, August 9, 10, 11, 1887
Seventh	Pittsburg, February 21, 22, 23, 1888
Eighth	New York, August 29, 30, 31, 1888
Ninth	Chicago, February 19, 20, 21, 1889
Tenth	Niagara Falls, August 6, 7, 8, 1889
Eleventh	Kansas City, February 11, 12, 13, 14, 1890
Twelfth	Cape May, August 19, 20, 21, 1890
Thirteenth	Providence, February 17, 18, 19, 1891
Fourteenth	Montreal, September 7, 8, 9, 10, 1891
Fifteenth	Buffalo, February 23, 24, 25, 1892
Sixteenth	St. Louis, February 28, March 1, 2, 1893
Seventeenth	Washington, February 27, 28, March 1, 2, 1894
Eighteenth	Cleveland, February 19, 20, 21, 1895
Nineteenth	New York, May 5, 6, 7, 1896
Twentieth	Niagara Falls, June 8, 9, 10, 1897
Twenty-first	Chicago, June 7, 8, 9, 1898

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A. J. De Camp
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W. McLea Walbank
F. A. Gilbert
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Samuel Scovil
H. M. Atkinson
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†Elected in place of A. M. Young, promoted.
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ORDER OF BUSINESS

TUESDAY, June 7th, 1898.

FIRST SESSION, 11 A. M.

1. President's Address
2. Announcements
3. Paper—"Analysis of the Cost of the Generation and Distribution of a Unit of Electricity." By CALVIN W. RICE
4. Topic—"Prices and Discounts for Electric Current and Methods of Billing Current to Customers"

SECOND SESSION, 3 P. M.

1. Paper—"Public Lighting With Relation to Public Ownership or Control." By ALEX DOW
2. Topic—"Legislative Policy as to Public Service Corporations"
3. Executive Session

MINUTES

OPENING OF THE CONVENTION

The twenty-first convention of the National Electric Light Association was called to order by President Insull, at eleven o'clock, a. m., June 7, 1898, at the Auditorium Hotel, Chicago.

President Insull read the following address:

Members of the National Electric Light Association.

LADIES AND GENTLEMEN: In calling to order the annual convention of your association, my dual capacity presents somewhat of an embarrassment to me. I am in doubt whether as president to enlarge upon the great growth of this association since its formation in this city on February 25th, 1885, or whether as a resident here to dwell at length upon the marvelous growth of the city in which we meet. Chicago and the industry with which we are identified have a somewhat close connection. The growth of the former, if measured from the point of view of the rapidity with which history is made, is, so to speak, the product of yesterday. The electrical industry, or, rather, that portion of it with which we are associated, is but little more than the product of to-day. If the growth of this city and that of our own industry are as great during the next thirteen years as the progress that they have achieved since the date of your first meeting here, I am sure that both the citizens of Chicago and the members of your association will have every reason to congratulate themselves. Speaking for those of my friends connected with the electrical industry in Chicago, and also for myself, I can assure you that it affords us very great pleasure to welcome you at this convention, and the fact of your meeting in this my home city, enhances not a little my high appreciation of the privilege of presiding on this occasion.

The officers of your association have had in mind, in preparing a programme for this convention, the importance of bringing before you subjects of interest in connection with central station management, and the papers to be read at our various sessions, and the topics mentioned for discussion, cover such a wide range that it would seem undesirable for me to occupy much of your time by way of introduction. The various gentlemen that have so kindly consented to read papers, will deal with such important questions as the cost of generating and distributing the product which we manufacture, transformer economy, and the rival claims of alternating currents and direct currents as means of distribution. The many problems which you have to solve in connection with the question of public lighting, and the cost of producing electrical energy by water power, will also be discussed.

STANDARD VERSUS SPECIAL MACHINERY

A matter that has called forth during the last year considerable discussion, is the question of the use of standard apparatus and the tendency towards the specification of special machinery on the part of electrical engineers. This course is not by any means confined to large work, but is followed by some engineers whether they are designing a small isolated plant or are projecting a large, modern central station. It would seem to me to be of paramount importance to the manufacturer and user that both should co-operate in eliminating, as far as possible, from the business the necessity of building and using special types of machinery. This can only be done by the adoption of standard specifications for various standard types of apparatus. A committee of the American

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Institute of Electrical Engineers has already taken this subject under consideration, and I believe that we shall be serving alike the interests of the manufacturers and users of electrical apparatus if we take some action with a view to co-operating with the institute and other bodies in this matter. In drawing attention to this subject, I speak with an appreciation of the positions of both manufacturer and user, having had more or less connection with the manufacture of electric apparatus and the manufacture of electric current. Constant duplication of parts, resulting in constant duplication of a given piece of machinery, means, as any manufacturer will tell you, constant reduction in cost. Variation from a given type means increased cost and even the wiping out of an apparent profit. In the last year or so there has been a great deal of discussion in England, prompted by the success of American manufacturers in obtaining large contracts for electric traction work in Great Britain, and the inquiry has often been made, how is it possible for American electrical manufacturers with high wages against them, to compete with English builders, whose scale of pay to their workmen is on a very much lower basis. If you will examine into the amount of electric-traction machinery manufactured in this country under a system of constant duplication and the use of special tools, and then visit the electrical establishments on the other side of the water, and note the tendency there towards specializing each particular job, you will soon recognize that the reason for low cost, and consequently low selling price, on this side of the ocean, is brought about by the fact that in America this class of work is largely designed by the manufacturer, and, as a natural result, is the duplicate of something already produced; while on the other side of the Atlantic the builder of the machinery works from the plans of the electrical engineer, which necessitates his producing something different to fill each different contract. In one case, the machinery is really manufactured; in the other case, the builder runs a jobbing shop. Unfortunately, during the last few years, American users of electrical apparatus have somewhat departed from the pursuance of what is really a fundamental principle of American manufacture, namely, the use of existing types, which are turned out in large quantities with special tools with a view to the lowest possible cost of production. The electrical engineer for the purchaser has been permitted to draw up specifications that have tended toward the specializing of apparatus, necessarily interfering with rapid manufacture and low cost of the product. The disadvantage to the manufacturer is apparent. It is turning our large electrical works from manufacturing establishments into jobbing shops, cutting down their capacity, increasing their labor cost and lengthening the time that it takes to produce a given article. Looking at it, therefore, from the point of view of the manufacturer, the capacity of his plant is reduced, and consequently his interest and general expense cost is higher; his labor cost is increased; and if he finds himself unable to increase his selling price, his shop must be run at a loss instead of at a profit.

The user is necessarily interested in low cost of production on the part of the manufacturer, as he cannot expect to purchase apparatus except at prices that yield a return to the maker. From this point of view alone it would seem to me to the interest of the user that he should co-operate with the manufacturer with a view to standardizing apparatus, eliminating unnecessary variations from a given type and providing specifications for machinery calling for a given capacity at a given efficiency. Such a course would lead to low cost of manufacture, and consequently low selling price, coupled with rapid production.

Another objection to special apparatus is the expense and delay in obtaining duplicate parts in case of break-down. The fear of delay under such circumstances often necessitates the user's carrying the duplication of his plant to a point entirely unnecessary when standard apparatus is used. Capital investment, and consequently interest cost, is thus increased, not only by the purchase of apparatus that of itself is expensive to build, but also by the duplication of investment which I have pointed out must of necessity follow.

A further point that should be borne in mind in connection with the lack of standard specifications, is the opportunity that it gives to the unprincipled manufacturer to dispose of his second-rate apparatus to the uninitiated. We talk of a machine having a given capacity; but under what conditions should it operate to develop this capacity, and how often does it occur that a dynamo machine is rated entirely too high and at the cost of its efficiency? How much miscellaneous material used in connection with the industry is absolutely unfitted for the purposes for which it is sold? Surely, all of us, manufacturers and users, are interested in maintaining the highest possible standard of work and eliminating alike from our central-station systems and the installations for our customers worthless appliances whose only recommendation is their apparent cheapness, whereas, as a matter of fact, they are really the most expensive that can be bought, because they are unfitted for the purposes for which they are intended.

A proper consideration of this subject would not embrace alone the apparatus we are ourselves in the habit of buying for use in connection with our plants, but also the appliances used in connection with customers' house wiring. It should be borne in mind that faulty apparatus from one cause or another resulting in a stoppage of the service of one or more customers, is, in the mind of the user of current, set down to the unreliability of the system as a whole. A central-station customer seldom discriminates between a contractor who supplies a worthless device and a company supplying him with current. Standard specifications should therefore cover, not alone the machinery used, but also the devices and material forming part of a customer's installation. This association has addressed itself at various times to the consideration of questions in connection with house wiring, and has co-operated with the National Board of Fire Underwriters and other bodies with a view to establishing rules to be followed by contractors. I strongly recommend that this matter be taken up on a broader basis than heretofore, and that in conjunction with the technical societies we invite the co-operation of the electrical manufacturers with a view to standardizing apparatus and the specifications therefor, whether for use in the central station itself or in connection with the distributing system.

I do not want my remarks on this subject to be taken as in any way censuring the many electrical engineers who have by their special training and natural ability done so much to develop the industry with which we are connected. From my experience I am satisfied, however, that, from the point of view of the user, the designing engineer who adapts his requirements to the standard apparatus of a first-class manufacturer, is able to produce a plant of more satisfactory character, and more economical to operate, than that designed by those engineers who, I regret to say, are sometimes influenced by the desire to use machinery that they can claim as their own handiwork rather than use something that would be quite as satisfactory and that has the advantage of being the regular product of an established manufacturer.

The consideration of the subject of standard specifications would naturally include the preparation of specifications with relation to the manufacture of incandescent lamps. For several years past a committee of this association has had this subject under consideration. It has been found practicable by a number of large central-station companies, connected with another association and buying from one manufacturer, to purchase their lamps under specifications that provide for the testing of samples of the product of the factory, the payment for lamps supplied being based on the results of the tests. It seems to me that it would be possible to adopt standard specifications under which our members could purchase their lamps from any reputable lamp manufacturer. The importance of this matter will be appreciated when it is remembered that the cost of lamp renewals per unit of output exceeds $1 per ton of the cost of fuel in operating a central station with the most modern steam plant.

SELLING PRICE BASED ON COST

It is of prime importance to central station managers that they should sell the product they manufacture, namely, electric current, to the greatest number of consumers at the lowest possible price, and yet obtain a reasonable profit. For a number of years, the basis of charge on the part of most companies has been a given unit price with discounts for quantity. In the early days of the business, some companies were in the habit of charging a fixed price per lamp per month, having no control whatever over the use of the product, but being necessarily responsible for the increased operating expenses caused by the wastefulness of customers, who could hardly be expected to economize, inasmuch as they paid exactly the same price for the use of light whether they burned it one or twenty-four hours a day. A majority of these companies, however, following this last method realized at an early date the absurdity of distributing that for which they were not paid, and as a result I presume we can fairly assume that electric-lighting business (with the exception of arc-light service) is run almost universally on a meter basis. It is therefore unnecessary for us to discuss the question as to whether the measuring of current is a desirable thing in our business, as it is now generally recognized as a necessity. If you will make a careful examination of the factors entering into the cost of current, you will very quickly come to a realization of the fact that interest is by far the most important single element, and that this item varies very considerably with the different classes of service furnished by a central-station company. The interest factor in cost depends upon the yearly average consumption of your product by the customer; or, to put it another way, you can figure your interest on the basis of so much per unit of output at maximum load. For instance, take the two probably extreme classes of customers to whom the central-station company supplies current for lighting purposes. On the one hand, you have an office building whose tenants use artificial illumination for only a very short space of time each day and only during the winter. On the other hand, you have a basement customer whose use of your product averages nearly one-half of the day of twenty-four hours during the whole year. Your investment to take care of each of these customers is practically the same, therefore your total interest cost must be the same in both cases; but if you distribute this interest cost over the actual units consumed, you will find that the tenant of the office building costs you for interest per unit of current sold many times more than does the occupant of the basement. There are of necessity as many different grades of customers between the two extremes I have mentioned as there are different classes of business and different characters of structures in which these businesses are conducted. Surely, if the cost of production varies according to the different conditions under which your customers use your product, it is but fair that the selling price per unit should vary correspondingly. If it does not, you, of necessity, encourage the use of electricity by customers whose business is unprofitable to you, and discourage the use of your product by customers whose business at a lower price would yield you a fair return. In past conventions the question of how to improve the day load for the purpose of raising the average output, what classes of business other than lighting should be encouraged to achieve this result, and the price at which we can afford to sell current to the operators of these different lines of business, have come up for discussion. At the last convention the realization of the fact that great differences exist in the elements governing the cost of product for different classes of lighting customers, was ably presented by Mr. Wright, and he pointed out that the improvement of your load-factor, the broadening of your curve, and the rendering less acute of your peak, are matters within your own adjustment, provided that you will realize, in considering cost with a view to making a selling price, that conditions are so dissimilar that the expense to you per unit of supplying two customers in the same block is likely to be widely different. Various plans have been adopted by a comparatively small number of companies to meet the conditions as we now know them to exist. Some companies have adopted the scheme of allowing certain special discounts provided the income per month per lamp connected exceeds a certain amount. Other companies charge one rate for current used during certain specified hours of the day and a much lower rate for the current used during the remaining hours of the day. A third method is a system of discounts based upon the total consumption of current during a given period, considered in connection with the maximum consumption at any time during that same period.

These various methods all have the same object in view, namely, the meeting of the conditions of each individual customer, and yet at the same time earning a fair return on all of the investment provided for all of your customers.

In discussing this matter I have referred to interest cost alone, because it forms so large a proportion of the total cost; but you will find that this same principle enters into a number of the other elements that go to make up your total cost. It would therefore appear to me that in considering the cost of generating electricity you should bear in mind that a large proportion of the items that go to make up the total are within your own control, and their amount per unit of output depends very largely upon the methods adopted in selling your product.

PUBLIC CONTROL AND PRIVATE OPERATION

A subject of growing importance to a number of our members is the question of the public ownership and operation of the undertakings now operated by electric lighting companies. The agitation in connection with this subject has called forth a great deal of discussion, partly by those interested in it simply with a view to extending the influence of political parties, and partly by serious disinterested thinkers who believe that the best interests of the greatest number are to be obtained by the creation of a municipal socialism, which, if carried to its logical conclusion, must ultimately result in municipalities performing, with others, such public-service work as we are engaged in, and also in producing the food we eat and the clothes we wear. To those occupied in the management of electric-lighting properties, it does not seem possible that the movement in favor of municipal operation of electric-lighting plants, based upon the assumption that a municipality can produce electricity cheaper than, or even as cheap as, a private corporation, is well founded. We all realize, from the close attention we have to give to our own affairs, that self-interest and the necessity of getting a return on our investment are the first essentials to the economical administration of large enterprises. While I do not pretend to claim that electric-lighting companies are beyond reproach, I wish to point out that many of the evils complained of as pertaining to corporate management are the direct results of the enforcement of unwise conditions through legislative action. Ill-advised efforts are often made by legislative bodies to secure advantages in the direction of control which cannot be obtained without giving an equivalent in protection to the industry.

This causes the investor to feel that his property is being attacked, and compels him to resist such legislation. The result is a feverish agitation, crimination and recrimination between the would-be improvers of municipal government and the owners of corporate properties without reaching a conclusion satisfactory to either. The fallacy of the so-called reformer's theory results from looking only at what he calls the injurious effects of corporate management without taking into account its indisputable benefits. He does not seek for the cause of the trouble. If reformers will take accurate account of all the points in the problem, they will discover that the evils complained of result from errors in legislation designed to determine the relations between municipal bodies and electric lighting companies. It seems to me that the claim that municipal operation is the universal cure for all diseases for which electric lighting companies are supposed to be responsible, merely proposes the substitution of political in the place of industrial management. This raises the question: Is the administration of municipal affairs in the various cities throughout this country so economical as compared with the management of private industries, and the class of service rendered so efficient, as to justify the increasing of the burdens already imposed upon municipal government? It appears to me that a correct division of power and responsibility requires political government to control private industrial management. Where political government and industrial management are merged into one interest, the power of control is seriously impaired, since a political administration cannot be reformed without overturning the party in power.

I cannot bring myself to the belief that the citizens of this great country are in fact opposed to large aggregations of capital in corporate form, as such aggregations are absolutely necessary to the operation of all great undertakings by private enterprise. It is as impossible to operate such vast affairs with individual capital, as a personally owned business, as it is for us to live without municipal, state and national governments. The misunderstandings that from time to time occur between communities and the managers of electric-lighting companies, will, to my mind, disappear entirely if the relations between the two are correctly founded on the basis of public control, with corresponding protection to the corporations operating this industry. It would seem to me to be a very proper function for this association to address itself to educating the public to a definite legislative policy that will be fair to the municipalities, securing to the public the best service at the lowest possible price, and protecting corporations by giving them franchises, which, while conserving municipal control, will insure to the investor the permanency of the undertaking.

COMPETITION IS NOT THE TRUE REGULATIVE FORCE

It is supposed by many who discuss municipal affairs that the granting of competitive franchises for public-service work is the true means of obtaining for users the lowest possible price for the service rendered, whereas, as a matter of fact, the exact opposite is the ultimate result. This is proved by results in all large cities where the most severe competition has taken place. Acute competition necessarily frightens the investor, and compels corporations to pay a very high price for capital. The competing companies invariably come together, and the interest cost on their product (which is by far the most important part of their cost) is rendered abnormally high, owing partly to duplication of investment and partly to the high price paid for money borrowed during the period of competition. The selling price of a service should be based on its cost, and in any business such as public work, where the investment is large and the annual turn-over is comparatively small, if the item of interest be unnecessarily augmented, it must be reflected in the price paid by public and private users.

While it is not supposed to be popular to speak of exclusive franchises, it should be recognized that the best service at the lowest possible price can only be obtained, certainly in connection with the industry with which we are identified, by exclusive control of a given territory being placed in the hands of one undertaking. In most European countries public-service operations enjoy exclusive franchises, under proper control, and are able to obtain capital for their undertakings at the lowest commercial rates, thus materially affecting the cost of their product, of which interest, as I have already stated, is necessarily so great a part. In order to protect the public, exclusive franchises should be coupled with the condition of public control requiring all charges for services fixed by public bodies to be based on cost, plus a reasonable profit. It will be found that this cost will be reduced in direct proportion to the protection afforded the industry. The more certain this protection is made, the lower the rate of interest and the lower the total cost of operation will be, and, consequently, the lower the price of the service to public and private users. If the conditions of our particular branch of public service are studied in places where there is a definite control, whether by commission or otherwise, it will be found that the industry is in an extremely healthy condition, and that users and taxpayers are correspondingly well served.

COMPENSATION FOR FRANCHISES

When prices for services are based on cost, it matters not whether or not, in the establishment of a system of legislative control, provision is made for paying a portion of the receipts direct to the municipality. If the public demands a percentage, surely we can afford to pay it, as it would simply be added as an item of expense, on which our selling price would be figured. If the public does not demand a percentage, this selling price would be proportionately less. It is simply a question as to whether our municipal bodies prefer to raise a portion of their income by taxing their citizens through the agency of public-service corporations, or whether they prefer to raise that portion of their income by collecting it direct from citizens themselves. Revenue raised by a percentage on gross receipts of the electric-lighting business would, at the present time, however, seem to be somewhat unfairly obtained in cases where the selling price is subject to legislative control and based on cost of service, as the result would be that a small minority of citizens using electricity would be forced to contribute largely to the public revenue, whereas the benefits enjoyed therefrom would be to the advantage of the whole community.

TAKING PRIVATE PROPERTY FOR PUBLIC USE

Another point that should be included in a proper scheme of public control, is a condition under which the municipality would have the right to purchase the undertaking. Such a right should include a direct obligation on the part of the municipality to purchase the property at a fair price whenever it is thought desirable that the industry should be operated by the municipality. The possibility of the exercise of the right of purchase by the municipality would of itself make it to the interest of the owners of the property to do their full duty in their relations to the public. On the other hand, if a community licenses a corporation to perform a certain public service, and if that corporation invests its money and develops its business, surely it is unfair for that community to go into the same line of public-service work itself without first purchasing the existing plant. If this is not done, the value of private property will be destroyed, without just compensation being made therefor, in an attempt to secure a public benefit. I do not believe that the people as a whole are so unfair as to demand that such a course shall be taken.

My recommendations on the subject, which I have just presented, are by no means original. Most public-service corporations in Great Britain are run on practically the bases indicated, and in more than one state in the union corporate legislation has taken the same direction.

I would summarize in just two sentences the position that I think we should take on this subject.

First—Franchises granted to public-service corporations should secure them the same degree of protection in their rights to their property as is enjoyed by other investments.

Second—Public control of charge for service based on cost plus a reasonable profit, and eliminating the factor of competition, is the proper safeguard for the interests of users, taxpayers and investors.

THE PRESIDENT: In my remarks just made, I have endeavored to touch upon a few subjects on which I had hoped we should have papers, but I failed to get the members of the association to respond to my request to prepare them. We have therefore placed the various subjects referred to in my opening address in the programme, under the head of topics for discussion; and I would therefore request you to keep your copies for future reference during the meeting. One of these subjects involves the basis on which we exist, and the other, the objects for which we exist. They are very important matters for us, and I think this association ought to take some kind of action concerning them.

ANNOUNCEMENTS

THE PRESIDENT: I have a number of letters here from various gentlemen who we had hoped would be able to attend.

The following letters were read:

"ORANGE, N. J., June 3d, 1898.

"SAMUEL INSULL, ESQ.,
"President National Electric Light Association,
"139 Adams street, Chicago, Ill.

"DEAR SIR: Mr. Edison requests me to acknowledge the receipt of your esteemed favor of May 16th, covering invitation to attend the annual convention, to be held at the Auditorium Hotel, Chicago. He very much regrets, however, to say that he will be unable to be present on this occasion, due principally to the fact that other engagements will absolutely prevent.

"Trusting that the meeting will be extremely interesting, and wishing your association every success, believe me

"Yours very truly,
"J. F. RANDOLPH."

"NEW YORK, May 20th, 1898.

"SAMUEL INSULL, ESQ.,
"President National Electric Light Association,
"136 Liberty Street, City.

"DEAR SIR: I wish to thank you herewith for the courteous invitation extended to me through your favor of May 16th, of which I fear I shall be unable to avail myself, as some duties will require my presence elsewhere.

"The selection of the Auditorium Hotel as the place of meeting, testifies to your wisdom and appreciation of the importance of satisfying the physical comfort of the members. I predict the coming meeting will be a great success.

"Yours very truly,
"N. TESLA."

"MONTREAL, May 25th, 1898.

"SAMUEL INSULL, ESQ.,
"President National Electric Light Association.

"DEAR SIR: I beg to thank you for your kind letter of May 16th, inviting me to be present at the annual convention of the association. It would have given me much pleasure to accept this invitation, but I regret to say that important business either detains me in Montreal or requires my presence in England.

"With many thanks and best wishes for the success of the convention, believe me to remain

"Yours truly,
"HENRY T. BOVEY."

"LYNN, MASS., May 20th, 1898.

"MR. SAMUEL INSULL,
"President National Electric Light Association,
"Edison Building, Chicago.

"MY DEAR SIR: Your letter of May 16th is received. It seems hardly possible for me to make it convenient this year to be present at the meeting of the National Electric Light Association, but I should be glad, under circumstances, to attend.

"I have a considerable amount of work here that needs personal attention, and which at this time is coming to a head.

"I thank you for the invitation you so kindly sent, and regret my inability to send any favorable response.

"Yours very truly,

"ELIHU THOMSON."

"BROOKLYN, N. Y., June 3d, 1898.

"MR. SAMUEL INSULL,
"President National Electric Light Association,
"Chicago, Ill.

"MY DEAR MR. INSULL: I am more disappointed than I can tell you that I am prevented from attending the National Electric Light Association's annual meeting, in Chicago. I had made all my plans, even to the purchase of tickets, and expected to leave on Saturday afternoon agreeably with my promise to you, but matters of such moment have arisen within the last two days, relating to our company here in Brooklyn, that I am positively prevented from leaving, as I could not do so without jeopardizing some important business contracts that are now being negotiated for my company here.

"Feeling the greatest interest in this convention and in the success of our association, the disappointment of not being present is felt very keenly.

"I have arranged, however, to have our electrician, Mr. Calvin W. Rice, prepare and read a paper, which I hope will be of some value to the members present.

"Wishing you all a delightful and instructive meeting, I am

"Very sincerely yours,

"A. M. YOUNG."

"CORNELL UNIVERSITY,
"ITHACA, N. Y., May 20th, 1898.

"SAMUEL INSULL, ESQ.,
"President National Electric Light Association,
"Chicago, Ill.

"DEAR SIR: Your letter inviting me to attend the annual convention of the National Electric Light Association was duly received. It would give me great pleasure to be present at this meeting, and I only regret that the dates are such as to conflict with other duties, so that I cannot possibly arrange to go to Chicago at that time. I have always esteemed very highly my position as honorary member of the association, and I hope in future years to be able to attend the meetings.

"Yours very truly,
"EDW. L. NICHOLS."

"28 CHESTER SQUARE, S. W., May 27th, 1898.

"DEAR SIR: In reply to your letter of May 16th, I am directed by Lord Kelvin to thank the president and committee of the National Electric Light Association for their kind invitation to the twenty-first convention, which, however, his Lordship is unable to accept, as his presence is required in this country at the present time.

"Yours faithfully,
"W. CRAIG HENDERSON.

"GEO. F. PORTER, ESQ."

"TECHNICAL COLLEGE, FINSBURY, LONDON, E. C

"DEAR SIR: I regret to say that I shall not be able to avail myself of your kind invitation to attend the forthcoming convention in Chicago in June.

"Yours faithfully,
"SILVANUS B. THOMPSON

"May 26, 1898."

"MANSION HOUSE BUILDINGS,
"LONDON, E. C., May 26th, 1898.

"G. F. PORTER, ESQ.,
"National Electric Light Association,
"136 Liberty Street, New York, U. S. A.

"DEAR SIR: I thank you for the kind invitation of President Insull and your association to be present at your convention, but I regret that business engagements will prevent my coming at present.

"Yours faithfully,

"R. E. CROMPTON."

THE PRESIDENT: We have some letters inviting us to avail ourselves of various courtesies that have been extended to us. They are as follows:

"CHICAGO, June 4th, 1898.

"SAMUEL INSULL, ESQ., President,
"139 Adams Street, Chicago.

"DEAR SIR: If, at any time during the meeting of the association to be held in Chicago next week, it would be of service to you, I should be very glad to place at the disposal of yourself and friends a special train for the purpose of a trip over this road and inspection of the power house. Kindly let me know if you decide to avail yourself of this favor and oblige

"Yours truly,

"W. E. BAKER,

"Superintendent for Receiver."

"CHICAGO, June 4th, 1898.

"SAMUEL INSULL, ESQ.,
"President National Electric Light Association,
"139 Adams Street, Chicago.

"DEAR SIR: It having been suggested that your association might be interested in taking a trip over our road in the newly-equipped electric cars, it would afford us great pleasure to arrange for a train at the old Congress street station, No. 47 Congress street, at some time convenient to you.

"Very truly yours,
"LESLIE CARTER,
"President."

"BUFFALO, N. Y., June 4th, 1898.

"MR. SAMUEL INSULL,
"President National Electric Light Association,
"Chicago Edison Company, Chicago, Ill.

"DEAR SIR: The steamship 'North West' will leave here Sunday evening, June 5th, and should arrive in Chicago about seven o'clock in the evening of June 8th. It was my purpose to permit a limited number of invited guests the opportunity of looking through the vessel, but if your association would like to visit the ship on the evening of arrival at Chicago, I should be very much pleased to extend the exclusive privilege to yourself and your association, thinking that it might be desirable for you all to visit the ship and look through her, so as to become familiar with the accommodations, before the Northwestern Electrical Association get aboard for their trip to Duluth.

"Will you kindly advise Mr. J. M. Hill, in Chicago, if it is your wish to have your association visit the ship on Wednesday evening, and, if so, he will let me know in time, so that the vessel may be in readiness to receive you.

"Yours truly,
"W. C. FARRINGTON,
"Vice-President."

"EXECUTIVE OFFICE,
"DETROIT, MICH., May 16th, 1898.

"*National Electric Light Association.*

"GENTLEMEN: The citizens of Detroit send you a hearty greeting, and through me, their executive, freely extend to your association the hospitality of our beautiful city, and assure you of a cordial welcome and attention if you will meet with us next year.

"Sincerely yours,
"WILLIAM C. MAYBURY,
"Mayor."

"COMMONWEALTH OF MICHIGAN,
"EXECUTIVE OFFICE,
"LANSING, May 11th, 1898.

"*To the National Electric Light Association.*

"GENTLEMEN: It gives me pleasure to have the honor of extending to you a cordial invitation to meet in Detroit in 1899. Citizens of Detroit and Michigan take especial pains in making visitors welcome, and all national gatherings receive particular attention.

"It can truthfully be said that no other city in the country has the advantages and convention facilities of the beautiful city of the straits. In the past half dozen years Detroit has unconsciously made for her-self the name of "Convention City," until to-day that title is applied to her by national bodies as they seek out available places for holding coming meetings, and to-day Detroit is the choice of more associations for the place of their next meeting than any other city in the country.

"Detroit's advantages as a convention city, that are worthy of particular notice, are too numerous to mention in a letter, but among them are the excellent facilities for visiting the beautiful parks and Belle Isle, numerous waterways, rapid railway service and splendidly paved streets for carriage drives, etc.

"All Detroit and Michigan will join in helping to make visitors happy, and I trust you will select Detroit for 1899.

"Very respectfully,
"H. S. PINGREE,
"Governor."

"DETROIT, May 16th, 1898.

"*To the Members of the National Electric Light Association.*

"GENTLEMEN: On behalf of the business interests of Detroit we extend to your association a most cordial invitation to hold its next annual association in our midst.

"You are probably aware of the convention advantages of Detroit, particularly its superb location, river attractions, fine climate and general modern improvements, but the warm hospitality of Detroiters to strangers you must witness to appreciate.

"We can assure delegates, members, officers and their friends a pleasant visit if you will meet with us.

"THE DETROIT CONVENTION AND
BUSINESS MEN'S LEAGUE,
"O. A. BIERCE,
"Secretary."

The following telegrams were also read:

"DETROIT, MICH., June 7th, 1898.

"*National Electric Light Association,*
"Auditorium Hotel, Chicago.

"Detroit's citizens earnestly urge consideration of their invitations to hold your next year's deliberations in their midst.

"WM. C. MAYBURY,
"Mayor."

"DETROIT, MICH., June 6th, 1898.

"*National Electric Light Association,*
"Auditorium Hotel, Chicago.

"Business Men's League sends greeting to members of National Electric Light Association, and extends cordial invitation to meet in Detroit next year.

"O. A. BIERCE,
"Secretary."

THE PRESIDENT: It is proposed to take a photograph of the gentlemen present, if they will permit us to do so, on the steps of the main hall of the Auditorium, to-morrow morning at half-past nine o'clock.

The Chicago Telephone Company has placed a special telephone service in one of the rooms near Mr. Porter's office, and has placed an operator in charge. It has given us the free use of its city and toll lines at any time of the day. This is for the use of members and visitors.

The American Telegraph and Telephone Company—long-distance—has placed its lines at our disposal at any time before nine o'clock in the morning and after six in the evening, for personal messages, so that any of you gentlemen that may be here from long distances may talk to your wives and sweethearts.

I will now call upon Mr. Calvin W. Rice, of Brooklyn, New York, to read a paper on the cost of the generation and distribution of a unit of electricity.

Mr. Rice read the following paper:

ANALYSIS OF THE COST OF THE GENERATION AND DISTRIBUTION OF A UNIT OF ELECTRICITY

The speaker has been asked at short notice to give this paper, which, considering the nature of the question, should have several months' labor for its preparation. Consequently no original work could be attempted.

I am fully aware of the responsibility of undertaking such a discussion, and will therefore confine the paper to a résumé of the most reliable data that can be secured from literature by recognized authorities during the last few years.

It is the intent of the paper to show what has been done, what is being done, and what is therefore possible, rather than to give theoretical tables. It is the intent also to show the advantage of watching each one of the various items that go to make up the total cost, and, by pointing out the proportions of each to the whole, to aid one in the discovery as to which particular items are disproportionately large in his plant.

Before taking up the consideration of the cost of operation of a plant, we should first consider the plant itself.

TOTAL INVESTMENT PER KILOWATT

In America, the variation in the investment per kilowatt is $200 to $750 per kilowatt capacity installed

In a few cases the figure is below $200, and in a few as high as $1,000; but in the great majority of cases the cost is below $400.

In this respect American practice is ahead of that of Great Britain and the Continent, where the majority of plants have a total investment of over $500 per kilowatt installed.

Later in this paper are given figures on some railway plants in Chicago costing less than $75 per kilowatt. I think these figures refer to stations alone, whereas the corresponding values for lighting plants include distributing systems also.

The importance of keeping down the investment per kilowatt need not be emphasized.

The principal items that go to make up the total investment, are real estate, steam or water-power plant, electric plant, distributing system and minor details.

In the first item we naturally find a great variation in the different plants. In country towns it runs as low as $25 per kilowatt, and in cities as high as $150 and over. In other words, there are some plants where the investment in real estate alone is greater per kilowatt than the entire investment is in others.

The investment in steam plant varies from $20 to $60, with figures on the electric plant slightly greater.

It is needless to say that the location of the plant ought to be considered with reference to all influences, each considered separately and reduced to a common method of comparison, *i. e.*, the dollars and cents value per year of each consideration.

For instance, in a large city which I visited a couple of weeks ago I observed a new station being erected not over one thousand feet from a river, yet five or six 1,000-horse-power, non-condensing engines were being installed. It is reasonable to assume that the convenience of that site to the main street of the city had a greater dollars and cents value than the consideration of condensing plus the difference in value of the land, as the company had the option to sell the present power site to the government and to buy a river site for less money.

In buying the steam and electric plant, however, it is essential to consider reliability above every other consideration. In emphasizing this point to make it the end sought while considering the merits of boilers, engines, water-wheels or generators, it should be viewed in its broadest sense. It is of assistance in examining bids on electrical apparatus or engines, to compare the prices per pound, and weight in pounds per kilowatt or horse-power, and in considering boilers, heating-surface and pounds per horse power, as well as price per pound.

The various methods of rating apparatus and of stating its ability to stand overloads are very confusing to the purchaser, so that comparisons by pounds develop features not otherwise noticed, but worth considering carefully.

Having decided whether or not it is economical to use simple, compound or condensing engines, decision as to the boiler pressure will follow as a matter of necessity, and will in turn decide in part whether tubular or water-tube boilers will be advisable. The price per horse-power of boilers is now not widely different.

The advantage of direct-connecting over belt or rope-drive is now recognized, so very little need be said. The amount of saving has been very carefully sought by Mr. Crompton, and in twenty-three of the largest English works the results have been tabulated as follows :

* COMPARISON OF FUEL USED

Works	Cost of fuel per unit sold. Cents	B. T. U. in fuel used per watt-hour	Efficiency of distribution. %	B. T. U. per watt-hour generated	Description of plant
		CONVERTED ALTERNATING-CURRENT SYSTEM			
Newcastle & Dist.. A	1.60	310	70	218	Steam turbine.
Leeds............. B	2.46	300	66	200	Alt'r Rp. Dr.
Bourne-mouth C	3.62	232	69	160	" " "
House-to-house .... D	3.86	265	66	175	" " "
Newcastle-on-Tyne E	1.28	262	66	178	" " "
Metropolitan .... F	3.60	232	66	158	Mixed system.
Eastbourne .... G	2.84	180	60.8	109	Alt'r Rp. Dr.
Exeter .... H	2.70	185	66	89	" " "
Average of B,C,D & F		245		161	
		MIXED SYSTEM			
City of London I	2.48	173	82	141	Mixed sys. dr.
Chelmsford .... J	1.92	146	76	112	" " "
Average .... I & J		159		126	
		CONVERTED CONTINUOUS			
Chelsea............. K	2.22	142			Dyns. driv. dir.
Oxford L	1.40	88.5	62	55	" Rp. Dr.
Average .... K & L		115		72	
		DIRECT SYSTEM			
Preston............. M	2.30	315	93	255	Dyns. driv. dir. by d'ble act. eng.
Liverpool......... N	1.90	186	75	148	Single act. eng.
Birmingham. ...... O	1.76	188	75	140	" "
Charing Cross and Strand............ P	2.26	147	90	182	" "
Hove .... Q	2.52	147	82	120	" "
St. James and Pall Mall .... R	1.74	116	95¼	110	" "
Bradford .... S	1.32	119	88.7	110	" "
Brighton ... . T	1.81	117	80	94	" "
Kensington........ U	1.74	116	86.5	100	" "
Westminster........ V	1.56	104	88	92	" "
Knightsbridge...... W	1.26	84	91.5	78	" "
Average.. .... N to W		133		112	
Ideal Works........	0.54	36¼	90	32.6	

"The table shows that the cost of fuel averages 46% higher where the dynamos are rope-driven than where the dynamos are direct-driven by high-speed engines."

Great stress is nowadays put upon high efficiency, and while this is important, reliability should be the principal feature.

In the present day of good design there is at best little to be gained in absolute efficiency, but the cost of energy, and the popularity of electric light and power will be very much affected, according as it is reliable.

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* "Cost of Electrical Energy," paper by Mr. R. E. Crompton, C. E., before the Institution of Electrical Engineers, April 26th, 1894.

Good regulation in the station is more important than high efficiency. Good regulation in the station means ability to use high-efficiency lamps.

The use of fifty-watt instead of fifty-eight-watt lamps means a saving of fourteen per cent directly in the lamps and in the copper losses. Relatively this increase in efficiency is much greater than is possible in any of the various types of boilers, engines or generators. Therefore the governing of the engine from no load to full load, and the regulation of the generators with load thrown off and on, should be carefully determined.

The value of accessories in the reliability of the plant and the reduction of labor and attendance is important. These accessories are as follows:

I. Feed-water appliances:
  (*a*) injectors
  (*b*) steam pumps
  (*c*) electric pumps
II. Boiler appliances (steam or electric):
  (*a*) forced draught
  (*b*) mechanical stokers
  (*c*) super-heaters
  (*d*) coal handling and storage
  (*e*) ash conveyors
III. Cranes:
  Mechanical or electrical
IV. Auxiliary electrical apparatus:
  (*a*) boosters
  (*b*) station motors

It is not ever advisable to drive the exciters from a motor taking current from the main generators on account of fluctuations being multiplied.

But under certain conditions the feed pumps, coal and ash handlers, overhead cranes and stokers may be driven with success and economy by either alternating or continuous-current electric motors.

Electricity as delivered at the switchboard is generated with economy, and can be used more advantageously than steam. The inefficiency of steam is illustrated in the following table, showing the indicated horse power and steam per indicated horse power of some of the auxiliary apparatus of the U. S. S. "Minneapolis."*

Name of Auxiliary	I. H. P. Lbs.	Steam per I. H. P. Lbs.
Pump of starboard condenser....	1.23	266
Circulating pump engine........	19	55
Starboard air pump.............	6.5	183
Centre air pump................	25	78
Vertical duplex fire pump........	1	205
Horizontal duplex fire pump.....	0.8	319
Same pump....................	6.4	156
Vertical duplex bilge pump	2.5	171
Fireroom feed pump (vertical duplex)........................	8.8	91
Same pump....................	1.6	243
Forced draft blower engine (flywheel)......................	16	77
Single cylinder horizontal flushing pump........................	1.4	194
An ice machine.................	6	70

The use of an oil-distributing system reduces amount of oil consumed and the attendance required.

The air-blast for cleaning around generators is a great assistance, saves time, labor and acts as an insurance against burn-out.

This apparatus can now be bought in a combined form, so that the same air-compressor and tanks furnish air for the oil circulation and for cleaning.

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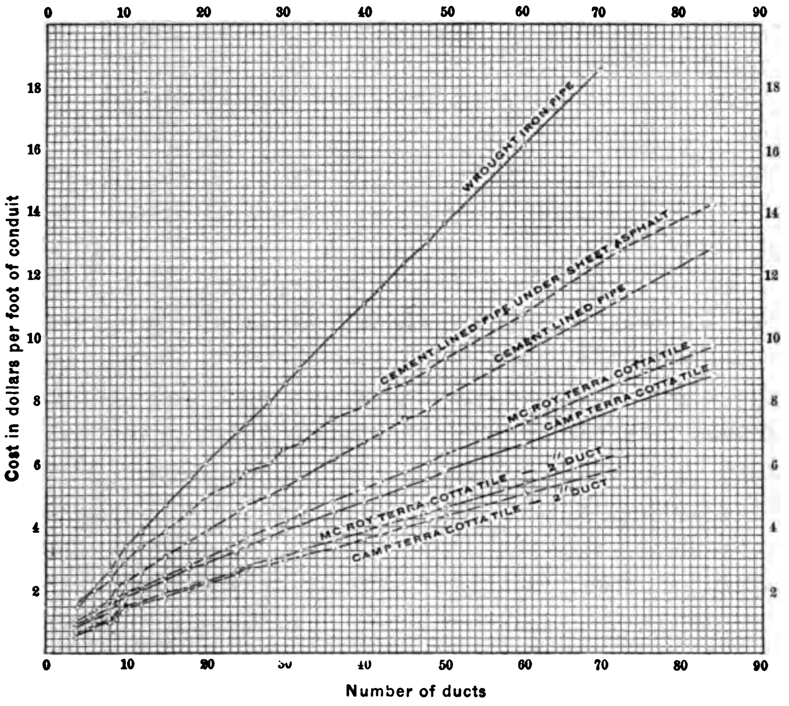
*Steam consumption of the auxiliary apparatus of the U. S. S. "Minneapolis," p. 383 March 26th, *Electrical World*, 1898.

DISTRIBUTION SYSTEM

From the station let us go to the cost of the distributing system, which is now becoming an enormous item of expense since underground conduits are required in many places. I give the following curves, showing the cost per foot of construction under Belgian block and asphalt, and with various materials of conduit. The cost of underground



construction complete is about four times that of overhead construction.

This curve was prepared by the electrical commission of the city of Baltimore, and from our work in Brooklyn these curves have been found to be practically correct. We are using cement-lined pipe only. The most costly construction is the wrought-iron pipe, the upper curve. The lower curves are for Camp & McRoy terra-cotta duct. The upper curves represent three-inch ducts and the two lower ones two-inch ducts.

In the choice of duct and insulation on conductors, again let me emphasize the importance of reliability. With such an enormous investment it is almost out of the question to consider material liable to break down.

In the tests which should be required of the cable two important features should be made prominent. First, the testing apparatus should be at least about fifty kilowatts capacity. The seven and eight-kilowatt testing transformers, which up to within a few years were considered sufficient, were a delusion. When it is stated that a cable must stand a test pressure, it should be required that that test pressure be maintained at least one hour, as the momentary test is not sufficient to develop faults. Make the insulation resistance requirements moderate, but insist on the test pressure from a large transformer being maintained one hour.

In the matter of joints employ only the most skilled labor.

PLANT MANAGEMENT

Cost per unit in what follows refers to 1,000 watts maintained one hour.

The price charged per unit is made up of cost and profit.

The cost may be subdivided as to

I. Generation and distribution; II. Maintenance; and III. Management.

It may again be divided into (a) material and (b) labor; (a) representing (1) fuel, (2) water and (3) supplies; (b) representing (4) wages and (5) superintendence.

Total cost or price.
- I. Generation and Distribution
  - (*a*) Material
    - (1) Fuel
    - (2) Water
    - (3) Supplies
  - (*b*) Labor
    - (4) Wages
    - (5) Superintendence
- II. Maintenance
  - (6) Material
  - (7) Wages
  - (8) Superintendence
- III. Management
  - (9) Directors
  - (10) Salaries
  - (11) Expenses
- IV. Profit
  - (12) Per cent on capital

(Crompton)

II. Maintenance is made up of (6) material, (7) wages and (8) superintendence, and

III. Management may be subdivided as to (9) directors, (10) salaries and (11) expenses.

As we compared total cost of plant per kilowatt and found it on the average to be under $400, calculations as to cost of operation of plant per unit output per year gives that figure to be, on the average, under fifty cents. That is, on the average, it requires fifty cents' worth of plant to generate and distribute one kilowatt-hour per year.

This immediately brings out an important point, namely, load-factor. This feature has been brought out with advantage by Mr. Hammond from data of the English companies. Such data are not obtainable yet in America,* so I quote in full from Mr. Hammond's paper.

"LOAD-FACTOR

" Former writers have not failed to dwell upon the marked effect which the *load-factor* has upon the costs of production, and in my estimation of the influences which bear upon that problem, I place load-factor directly after *output*. Without the latter the most favorable load-factor is useless, but combined with a healthy output, a favorable load-factor greatly reduces costs.

" So convinced is Mr. Arthur Wright of the importance of load-factor, that he offers to supply all his customers at three cents per unit for any consumption beyond an average of one hour per day of their maximum demand throughout the year.

" The advantages arising from a high load-factor are, however, universally acknowledged, and I therefore pass on to lay before you the data in connection with it that I have been able to collect.

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* Since writing this paper I have learned that Massachusetts has initiated this feature; and I understand that this year data, similar to what follows here for English companies, will be required from every one of the stations in Massachusetts. The data blanks will be distributed by the Gas and Electric Light Commission. The January report for this year is a very interesting report, and, if you have not obtained it, I advise you to write for it. It gives valuable data of all the gas and electric light companies of the state.

"These data are not demanded by the Board of Trade, and I am much indebted to those works engineers who have responded to my request for information on this head.

"I use 'load-factor' in the sense of the ratio of the actual units generated to the product of the maximum of the year and the total hours of the year; the 'load-factor,' therefore, of 1896 being obtained by multiplying the maximum load of 1896 by 8,784 (*i. e.*, 366 days by twenty-four hours), and of 1897 by 8,760.

"Though it appears to be the custom at every works to record the maximum load, the 'units generated' are in the majority not arrived at by meter, but by calculation, and in some by a process which one of my correspondents describes as 'cooking.'

"Under these circumstances I have hesitated about dealing with the data, but, finally, being convinced of the absolute accuracy of a portion, and of the approximate accuracy of the bulk, I have decided to set it out, leaving the members of the Institution to convince themselves in particular cases as to whether the 'units generated' have been arrived at in an accurate manner."

TABLE SHOWING (a) LOAD-FACTOR AND (b) UNITS USED IN DISTRIBUTION—PROVINCIAL UNDERTAKINGS

Works	Year	Units sold to consumers, including public lighting	Total units generated	Maximum load of year, kilowatts	Load-factor, per cent of units generated to output of maximum load in use constantly throughout year	Ratio of units used in distribution and unaccounted for to units generated, per cent
Aberdeen	1896	210,185	286,649	343	7.85	9.46
Aberdeen	1897	287,072	317,552	369	9.82	7.54
Ayr	1896	124,924	191,886	129	16.98	30.10
Bedford	1896	158,238	208,106	200	11.81	18.65
Bedford	1897	255,990	342,354	270	14.47	19.26
Blackpool	1896	403,667	596,340	590	11.50	31.66
Blackpool	1897	631,942	731,239	800	10.43	11.51
Bournemouth	1896	281,310	394,724	401	11.20	26 13
Bournemouth	1897	334,406	513,248	486	12 65	32.56
Bradford	1896	813,6 3	874,525	1,040	9 59	5.35
Bradford	1897	993,588	1,104,496	1,123	11 22	8.08
Brighton	1896	1.388,821	1,658,576	1,295	14.58	14.02
Brighton	1897	1,992,527	2,440,171	1,763	15 80	13.76
Bristol	1896	650,758	861,156	766	12.69	22 25
Bury	1897	64,162	71,790	91	9.00	5.32
Cheltenham	1896	105,500	179,000	157	12.98	32.07
Coventry	1896	51,114	79,114	100	9.00	25.20
Coventry	1897	79,583	128.845	126	12 82	30 56
Dover	1896	154,200	207,027	154	15.34	22.82
Dover	1897	234 074	317,190	...	....	. .
Dublin	1896	473,547	718.074	511	15.99	32.10
Dublin	1897	518,312	760,067	541	16.04	29 86
Dundee	1896	254,278	319,149	346	10.50	11.97
Ealing	1896	246,902	379,857	350	12.38	32.16
Eastbourne	1896	208,094	359,288	221	18.56	39.42
Eastbourne	1897	240,806	402,068	257	17.09	37.14
Edinburgh	1896	1,721,578	1,917,504	1 621	13.48	7.00
Halifax	1896	177,500	259,740	242	12.21	25.41
Halifax	1897	240,000	333,000	296	12.12	20 43
Hanley	1896	247 881	320,905	325	11.24	21.37
Hanley	1897	351,762	400,590	376	12.16	10.93
Hastings	1896	294,000	400,360	266	17.13	25.30
Hastings	1897	338,705	466,362	310	17 17	26.32
Hove	1896	195,915	239,779	253	10.78	12 32
Hove	1897	268,243	311.129	310	11.45	10.40
Kingston-on-Thames	1896	155.681	178,681	152	13 46	9.51
Kingston on-Thames	1897	194,268	221,268	208	12.46	9.01
Lancaster	1896	98,977	110,932	119	10.61	7.72
Lancaster	1897	134,717	146,631	190	8.80	5.83
Leeds	1897	833,280	1,190,000	1,010	13.44	27 48
Manchester	1896	2,508.588	3,028.357	2,738	12 62	8.36
Newcastle District	1896	503.894	900,197	559	18.33	39.88
Newcastle District	1897	600,971	1,041, 29	464	26.96	38.27
Newcastle-on-Tyne	1896	535,953	864,013	580	16.95	34 65
Newcastle-on-Tyne	1897	660,906	1,054,660	700	17.15	35.59
Newport	1896	195 932	293,089	192	17.45	28.29
Nottingham	1896	171,654	183,694	255	8 20	5.00
Nottingham	1897	297,185	316,638	400	9.01	5.00
Oxford	1896	260,595	426,066	321	15.14	33.69
Oxford	1897	313,037	511,845	392	15.02	33.68
Pontypool	1896	35,011	38.231	68	6 39	5.82
Pontypool	1897	40,483	44,776	75	6.81	6.39
Portsmouth	1896	839,392	900.490	660	15.57	....
Preston	1896	320,500	349,920	354	11.28	4.83
Preston	1897	371,301	408.111	428	10.80	5.95
Reading	1896	82,165	96,351	178	6 16	9.38
Reading	1897	123 702	138,947	216	7.37	7.68
Richmond	1896	97,044	105,771	135	8.92	6.46
Richmond	1897	138,916	152,052	165	9.38	7.27
Salford	1897	111,142	245,397	231	12.12	47.83
Sheffield	1896	483,427	636,071	648	11.27	23.99
Sheffield	1897	747,063	1,043,428	886	13.44	28.37

Works	Year	Units sold to consumers, including public lighting	Total units generated	Maximum load of year, kilowatts	Load-factor, per cent of units generated to output of maximum load in use constantly throughout year	Ratio of units used in distribution and unaccounted for to units generated, per cent
Southampton	1896	131.843	157.550	187	9.59	14 09
Southport	1896	245.515	335,864	257	14 91	24 28
South Shields	1897	109.543	128.379	126	12 53	15.67
Sunderland	1897	116,440	216,282	224	11.00	16 82
Taunton	1896	126,840	164.394	146	13.01	19 01
Taunton	1897	140.019	1 8.562	165	12.35	17 93
Walsall	1896	67,170	110,491	94	18 38	32 71
Walsall	1897	96,376	145,606	155	10.72	27.53
Whitehaven	1896	178,378	199 051	126	17.96	8.87
Whitehaven	1897	178,072	199,473	170	13 39	7 72
Worcester	1896	333.644	424.221	310	15 57	20.02
Worcester	1897	4 8 830	559,275	336	19.00	25 97
Yarmouth	1897	190,000	271,420	213	14.54	25.28

METROPOLITAN UNDERTAKINGS

Works	Year	Units sold to consumers, including public lighting	Total units generated	Maximum load of year, kilowatts	Load-factor, per cent of units generated to output of maximum load in use constantly throughout year	Ratio of units used in distribution and unaccounted for to units generated, per cent
Charing Cross	1896	1,944,402	2,305,721	1,066	24.69	12.98
Charing Cross	1897	2,615 508	3,167,214	1,378	26 25	14.45
Hampstead	1896	392,233	515,578	440	13.34	21.46
Islington	1897	503.572	618,929	585	12 66	15.39
St. James	1896	2,401,431	2,687.965	2,052	14 91	9.59
Westminster	1896	3,503,054	4,069,184	3,000	15.44	12.65
Westminster	1897	4,355,781	5,046,500	3,650	15 78	12.47

From paper by R. Hammond, before Institution of Electrical Engineers, March 24th, 1898.

From these tables there is another point to be learned, namely, the percentage of units generated that are unaccounted for. This percentage is even greater in gas companies, and it is interesting to watch the reports from year to year and to see the improvement in this matter. The Massachusetts report of all the gas companies of that state gives the exact number of feet unaccounted for in each company. These items, added together, in 1897 amounted to 285,000,000 feet. One gas company lost thirty-six per cent of its output, and quite a number over twenty per cent.

The largest percentage of unaccounted-for units in the English electric stations generating over a million units, appears to be twelve and one-half per cent.

Quite a number having an output of 500,000 units have thirty-three per cent. One station loses forty-seven per cent.

These figures with respect to electric lighting are not comparable with gas, for the reason that we allow the larger portion of the loss as necessary to the distribution. I have no doubt but that a great saving may be made in our stations if attention is brought to this feature.

To go back to the total cost per unit, we find, comparing again the English stations, as I have been unable to obtain such data on American stations:

The following table by Hammond gives the best recorded cost for the years 1894, 1895 and 1896 in Great Britain.

RECORD COSTS

TOTAL COSTS

1894

Units sold (kilowatt-hours) between	Place	Year of operation	Cost per unit sold
100,000 and 200,000	Norwich	1st	5.08c.
200,000 and 350,000	Leeds	2d	6.22c.
350,000 and 600,000	Brighton	3d	4.60c.
600,000 and 1,000,000	Kensington	4th	5.72c.
1,000,000 and 1,500,000	Manchester	1st	4.34c.
1,500,000 and 2,000,000	St. James	5th	5.88c.
2,000,000 and 2,500,000	Westminster	4th	5.38c.
2,500,000 and 3,000,000	Metropolitan	6th	9.04c.
3,000,000 and upward	....	...	.....

1895

Units sold (kilowatt-hours) between	Place	Year of operation	Cost per unit sold
100,000 and 200,000	Burnley	2d	4.44c.
200,000 and 350,000	Dundee	3d	4.60c.
350,000 and 600,000	Leeds	2d	4.10c.
600,000 and 1,000,000	Edinburgh	1st	3.34c.
1,000,000 and 1,500,000	Charing Cross	4th	4.42c.
1,500,000 and 2,000,000	Manchester	2d	3.60c.
2,000,000 and 2,500,000	....	...	.. ...
2,500,000 and 3,000,000	Westminster	5th	4.62c.
3,000,000 and upward	City of London	4th	7.00c.

1896

100,000 and 200,000	Whitehaven	3d	3.50c.
200,000 and 350,000	Preston	4th	3.88c.
350,000 and 600,000	Norwich	3d	4 22c.
600,000 and 1,000,000	Portsmouth	2d	3.42c.
1,000,000 and 1,500,000	Glasgow	5th	3.84c.
1,500,000 and 2,000,000	Edinburgh	2d	2.26c.
2,000,000 and 2,500,000	St. James	7th	4.58c.
2,500,000 and 3,000,000	Manchester	3d	2.90c.
3,000,000 and upward	Westminster	6th	4.18c.

We find the cost of coal varies from $3.50 to $5 per ton, and yet the cost of fuel per unit has been kept down in a great many plants to one cent. So far as I am advised, there is only one state in our Union which gives such data officially, namely, Massachusetts.

A very interesting report of one of the continental plants is that of the polyphase station of the Budapester Allgemeine Electricitäts Gesellschaft:

*This station has been in operation since 1893. The electric light in Budapest is supplied by two large central stations, one working on the polyphase system and the other on the simple alternating system. The polyphase currents are transformed into continuous current by rotaries to 230 volts on the three-wire system.

The station consists of six 300-kilowatt, two-phase generators driven by triple-expansion engines. The coal is Ostrauer nut, and makes 7.4 per cent refuse. On an average during the winter months the efficiency of the entire system is sixty-seven per cent. The results of the plant are given in the following table:

	1894	1895	1896
Gross production.......	1,200,000 units.	1,900,000	2,800,000
Highest load...........	15,000 16-c. p. l.	17,000	21,000
Lowest load............	2,000 16-c. p. l.	3,000	9,000
Gross watt-hours per lb. of coal..............	432	575	571

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*London *Electrician*, June 18th, 1897.

Consumers pay twenty cents a unit for light and sixteen cents for power.

*I give below the average cost of coal and contract price per arc lamp per year in about one thousand stations in the United States. No distinction in price per 2,000 or 1,200 candle power is made in averaging, on account of the great variation in price; a 2,000-candle-power lamp in one place with high-cost coal sometimes selling for less than a 1,200-candle-power with low-price coal.

State	Hours per year	Coal per ton	Contract per year	Price per hour	C. P. per hour for 1c.
Alabama	4,000	$1.92	$89	$0.021	791
Arkansas	3,396	2.30	121	.034	390
California	2,885	7.00	120	.045	449
Colorado	3,413	3.18	129	.042	558
Connecticut	2,730	4.28	86	.035	452
Delaware	4,000	2.32	110	.028	728
District of Columbia	4,000	......	106	.027	452
Florida	2,179	Wood	118	.054	222
Georgia	3,434	1.36	84	.034	775
Idaho	4,000	W. P.	114	.028	703
Illinois	2,789	1.19	77	.031	654
Indiana	2,682	1.79	79	.033	634
Iowa	2,870	1.57	86	.032	641
Kansas	2,734	2.02	97	.040	532
Kentucky	3,063	1.20	88	.032	672
Louisiana	4,000	2.38	128	.032	627
Maine	2,629	5.00	67	.031	575
Massachusetts	2,705	4.05	94	.037	375
Maryland	4,000	3.00	128	.032	626
Michigan	3,465	2.70	77	.024	748
Minnesota	3,133	3.41	98	.036	606
Mississippi	2,179	2.33	102	.047	367
Missouri	2,917	2.54	83	.032	667
Montana	4,000	4.00	131	.033	440
Nebraska	2,894	2.21	109	.041	465
Nevada	3,680	9.50	144	.039	306
New Hampshire	2,583	4.42	82	.036	444
New Jersey	3,615	2.70	105	.032	611
New Mexico	3,275	3.92	123	.045	558
New York	3,387	2.87	94	.028	627
North Carolina	2,572	3.30	97	.029	521

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*General Electric Co. Lighting Dept. Statistics.

State	Hours per year	Coal per ton	Contract per year	Price per hour	C. P. per hour for 1c.
North Dakota	4,000	$6.35	$120	$0.030	666
Ohio	3,350	1.56	79	.025	785
Oregon	3,689	W. P.	128	.035	569
Pennsylvania	3,931	1.56	86	.022	869
Rhode Island	2,912	3.85	102	.037	459
South Carolina	3,088	2.65	83	.031	501
South Dakota	3,680	5.50	125	.034	590
Tennessee	4,000	2.08	88	.022	765
Texas	3,472	3.13	109	.037	615
Utah	3,545	2.63	75	.023	872
Vermont	2,254	4.37	85	.039	630
Virginia	3,723	3.07	76	.022	651
Washington	3,479	2.75	128	.039	510
West Virginia	3,089	.90	79	.027	639
Wisconsin	3,057	3.13	81	.030	630
Wyoming	3,545	1.58	166	.052	352
Total average	3,326	$3.03	$101	$0.034	580

46 states—1,000 central stations.

*Statistics on English lighting plants:

	K. W.	Cost plant per K. W. installed	Cost per unit	Average selling price
Bristol	945	$517	6.38c.	10.62c.
Brighton	1,200	601	4.72c.	9.42c.
Bradford	1,400	255	4.48c.	9.56c.
Dover	525	270	8.34c.	10.76c.

The highest point for cost of fuel of any of these enterprises was 3.24 cents per kilowatt-hour, and the lowest 1.08 cents; but the conditions are so different that an analysis cannot be made, although the Brighton plant is one that is handicapped.

A, B, C and E in the following table are large stations containing the most expensive machinery. No expense has been spared in their construction, and, in consequence, fixed charges are extremely high.

Station D is a representative city station of moderate cost and high efficiency.

**Electrical Engineer*, p. 393, April 14, 1898. Claud P. D'Oyly.

* RAILWAY PLANTS—COST PER UNIT

Station	Boilers	Pressure	Style of engines	Cond. or non-cond.	Style of generators	Coal	Cost of coal per net ton	Pounds of coal per unit	Pounds water per unit	Cost of coal	Operating supplies exclusive of coal	Labor operation	Supplies, maintenance	Maintenance labor	Maintenance buildings	Total
A	W. T.	160	Cross comp.	C	Direct.	Anth.	$2.40	2.60	7.6	$.0028	$ 0005	$.0024	$.0003	$ 0001	$.0001	$.0061
B	W. T.	160	Trip. exp'n	C	Belt	Bit.	3.50	3.50	9.8	.0052	.0008	.0023	.0006	.0005	.0002	.0096
C	W. T.	160	Cross comp.	C	Belt	Anth.	2 40	3.11	7.7	.0033	.0008	.0044	.0002	.0005	.0001	.0093
D	W. T.	160	Tand. comp.	N	Belt	Anth.	3.15	3.65	9.3	.0051	.0009	.0030	.0001	.0001	....	.0092
E	W. T.	160	Cross comp.	C	Belt	Anth.	2.07	3.50	8.0	.0033	.0010	.0043	.0003	.0006	.0001	0096
F	W. T.	140	Cross comp.	C	Belt	Cumb. bit.	2.90	3 80	9.3	.0056	...	...	....	....	....	.0100
G	W. T.	140	Cross comp.	C	Belt	Cumb. bit.	3.23	4.00	9.4	.0065	....	....	.	...	....	.0109
H	W. T.	150	Cross comp.	C	Belt	Cumb. bit.	3.05	4.40	8.5	.0068	....	...	....	....	....	.0112
I	W. T.	150	Tand. comp.	C	Direct	Cumb. bit.	2.69	4 20	..	.0050	.0006	.0042	.0002	.0004	.0001	.0105
J	W. T.	160	Vert'l comp.	N	Di rect	Bit. scrn'g	1.40	6.20	6.9	.0057	.0004	.0033	.0004	.0001	....	.0098
Average......							2.68	3 90	8.6	.0049	.0007	.0034	.0003	.0003	.0001	.0097

Stations F, G and H are city stations of moderate cost. They are not of absolutely modern construction, but at the time of their erection were as perfect as money could make them.

Station I is a model station of small size, running an extremely variable load.

Station J is a large city station running under favorable conditions.

The points of interest in the table are:

1st. Cost of coal. This averages one-half cent per unit. This is less than in the ideal station of Mr. Crompton. We get the advantage of cheaper coal in America. The wages item is less in these railway plants than in any English lighting station, but it should be remembered that the figures on these railway stations refer probably to generation only.

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* *Street Railway Journal*, January, 1897, L. D. Tandy.

If we take the pounds of coal per unit, and divide 1,000 watt-hours by it, we shall obtain 256.

At this point, it is interesting to turn back to your 1896 meeting in New York, and to the paper by Mr. Swetland, chairman of the Committee on Data.

From the examination of eighty-one reports using coal as fuel, the average efficiency is 108 hours per pound of coal.

We are thus able to compare these two series of stations, and find that the average efficiency of the lighting is less than half the railway companies; also that the average of these railway stations is above the highest efficiency of the 1896 report, but was equaled in 1895 in the report of one lighting station only.

It is interesting to compare these reports with the Budapest Gesellschaft, where the lowest efficiency for the last three years is 432 watt-hours per pound coal, showing there is yet much to be gained.

Below is the report of some of the Chicago railway plants:

*COST OF OPERATING RAILWAY PLANTS

	C. C. Ry. Co. No. 1	C. C. Ry. Co. No. 2	M. W. S. Sta.
Kilowatt capacity	5,250	5,280	4,500
Cost per kilowatt installed	$73.33	$75.75	$141.33
Cost of station	385,000.00	400,000.00	363,000.00
Units, output per year	1,067,900	2,375,000	1,460,000
Fuel per unit	$0.0049	$0.0039	$0.0033
Water per unit	.0004	.0003	.0001
Labor per unit	.0022	.0007	.0021
Supplies per unit	.0001	.0001	.0004
Total	$0.0076	$0.0048	$0.0059
Interest	.0018	.0008	.0022
Depreciation	.0015	.0007	.0018
Total	$0.0033	$0.0015	$0.0040
Repairs	.00002	.00003	.00003
Total	$0.0109	$0.0064	$0.0103

*_Street Railway Journal_, May, 1897.

A carefully-prepared paper by Mr. Horatio A. Foster on the cost of steam power, read before the American Institute of Electrical Engineers a year ago, emphasizes the fact that there are very little reliable data on American plants.

Below are his results on twenty-two plants.

"The plants on which tests were made for cost of power were:

"Two electric lighting stations
"One grain elevator
"Three water-works pumping stations
"Two flouring mills
"Six cotton mills
"Four newspaper and printing offices
"One department store
"One furniture manufactory
"One bakery
"One glazed and fancy paper manufacturing company.

"It will be seen that in rated capacity the plants vary from 40 horse power to 2,500, and in value per rated horse power from $23 to $89 in steam-power plants, or as high as $368 in water-works pumping stations.

"While the type of boiler used leans largely to the plain, old-fashioned return-tubular, with the exception of the cotton mills, the types of engines are almost as varied as the number of plants.

"In fuel, soft coal or slack of soft coal largely predominates, and a considerable use of mixtures of the latter with dust from the yards and hard-coal slack will also be noticed, which is largely due to efforts to reduce the smoke nuisance."

Engines									Values		Labor				
				Cylinder							Engi-neers		Fire-man,etc.		
No. of plant	No. of engines	Type	How run	Diameter, high, inches	Diameter, low, inches	Stroke, inches	Revolutions per minute	Rated h. p.	Total power plant	Per rated h. p.	No.	Rate per month	No.	Rate per month	Purposes for which steam is used other than for power from same boilers, at same time
1	1	Corliss	Non-condensing	22		48	80	380	$14,865	$39.12	2	$78	2	$60	Exhaust heating during winter
2	1	Cummer	Condensing	22.1		42	78	250	11,000	44.00	2	78	2	45	
3	1	Corliss	Non-condensing	16		36	86	125	18,300	89.27	1	125	2	48	Steam tables, elevator and other pumps
	1	Slide-valve	Used occasionally	12		20	162	80			2	62			
4	1	Slide-valve	Non condensing	12		16	125	40	2,337	58.42	1	65			Steam tables; exhaust for building in winter
	1	Compound automatic	Non-condensing	8	14	14	194	65							
5	1	Vertical	Non-condensing	16 7/16		20	74	65	1,500	23.08	1	90			Steam tables and neighboring building
6	1	Vertical compound	Condensing	15	30	20	60	100	10,143	46.10	1	125	1	52	Steam tables; heating building in winter
	1	Straight-line	Non-condensing	10		16	235	60			2	65	1	40	Elevator and other pumps
	1	Ball	Non-condensing	10		12	275	60							
7	1	Corliss compound	Condensing	30⅜	56	60	68	1,500	100,000	40.00	1	100	4	55	
	1	Corliss compound	Condensing	26	42	48	75	1,000			2	75	4	50	
											2	50			
8	1	Wheelock	Non-condensing	17		38	100	165	11,200	67.88	1	45	1	36	
9	2	Holly double-compound	Condensing	36	72	48	16		632,000	287.90	1	167	9	61	
	1	Holly double-compound	Condensing	33	66	48	16				3	87	2	40	
	2	Worthington compound	Condensing	38	66	50	10				7	40	6	40	
	1	Worthington compound	Condensing	29	50	50	10				7	45			
10	2	Holly compound	Condensing	12	24	22	21		40,478	367.98	1	100	2	45	
											1	75			
11	2	Holly compound	Condensing	12	24¼	22	19		28,000	254.54	1	100	2	48	Part of last year for electric-power station in same building
											1	50			
12	1	Slide-valve	Non-condensing	28		36	78	300	9,500	31.66	1	78	1	45	For small electric-light plant occasionally
13	2	Compound automatic	Non condensing	8	13¾	12	235	65	7,730	46.85	1	100	1	43	For elevator and other pumps and to help exhaust in winter
	1	Westinghouse	Non condensing					35			2	65			
14	1	Buckeye	Non-condensing	12		22	140	65	4,500	69.23	1	75	1	48	For heating ovens and part of building
											1	56			
15	1	Slide valve	Non-condensing	12		12	280	80	3,000	37.50	1	48			To help exhaust in winter. Exhaust used for dry rooms all the year
16	1	Wright	Non-condensing	22¼		42	68	200	7,000	35.00	1	78	1	45	To help exhaust in winter. Exhaust used for dry rooms all the year
17	1	Corliss triple-compound	Condensing	24	1-34 2-36	60	62½	1,200	57,500	47.92	½	100	2	35	1st asst. eng. at $32 and one coal wheeler at $30
18	1	Corliss dbl.-tand.-comp.	Condensing	22	40	60	68	1,000	71,434	71.43	1	75	2	35	One oiler at $35 for slashers and vapor
19	1	Corliss double	½-condensing	22		60	54	600			1	75	2	39	Exhaust from one cylinder of Nos. 1 and 2 for slashers
	1	Corliss double	½ condensing	22		60	64	600			1	100	2	32	Live steam for heating and vapor
	1	Corliss cross-compound	Condensing	24	44	60	68	800			1	50	1	42	
	1	Corliss cross-compound	Condensing	22	40	60	65.8	500	146,550	58.75	2	42	3	36	Watchman at $48
20	1	Corliss cross-compound	Condensing	28	52	60	66¼	1,200			1	90	3	36	One coal wheeler at $30
	1	Corliss double	¾-condensing	28		60	57	800	110,000	55.00	2	36	2	26	Exhaust from slashers and vapor
21	1	Corliss cross-compound	Condensing	28	52	72	63	1,400	68,789	49.14	1	100	2	38	Two wheelers at $33
22	1	Corliss cross-compound	Condensing	28	52	72	57	1,200	64,000	55.33	1	67	1	40	One fireman at $34, one wheeler at $47,

No. of plant	OUTPUT						OPERATING EXPENSES		
	Average horse power developed	Per cent of total engine capacity	No. of days	Time per day		Hours per annum	Fuel	Wages	Supplies
				Hours	Minutes				
1	296.7	78	297	24	....	7,128	$26.20	$10 95	$1 68
2	210.9	85	290	24	.	6,960	22.00	13.26	3.94
3	58.8	47	365	24	....	8,135	36.30	44.60	9.90
4	12.4	31	361	9	...	3,067	48.93	84.12	9.13
5	21.5	33	361	9	....	3,711	28 82	51.09	7.34
6	70 4	32	365	23	....	7.461	34.00	55.07	5.09
7	1,345.5	54	365	11	....	4,008	11.75	8.90	.55
8	129.3	78	365	12	27	4,544	18.25	9.82	.58
9	1,352	62	365	24	....	8,760	13 76	13.00	2.74
10	30 7	33	365	24	....	8,327	36.71	81.62	8.70
11	42 4	39	365	24	....	8,755	26 54	54.49	3.96
12	173	58	313	3	....	939	11 98	8.53	1.05
13	53	32	309	15	30	4,790	24.43	25.50	2.35
14	20.9	32	365	24	....	8,110	49.30	55.30	8.83
15	31.9	41	330	10	20	3,410	9.58	8.74	2.92
16	106.7	84	313	9	50	3,075	5.46	7 48	1.36
17	1,174.8	98	306	9	40	2,958	7.62	1.82	.54
18	926	93	307	9	40	2,968	8.64	2.20	.62
19	2,422	97	306	9	40	2,958	11.12	3.18	.81
20	1,909.7	95	306	9	40	2,958	8.76	2 26	.82
21	1,278.7	91	293	9	40	2,831	7.40	2.41	.46
22	1,010.86	84	306	9	40	2,958	8.89	2.24	1.35

No. of plant	OPERATING EXPENSES			FIXED CHARGES					Cost per horse power
	Repairs	Water	Total	Interest	Depreciation	Insurance	Taxes	Total	
1	$5.77	$0.96	$45.56	$2.55	$3.52	$1.07	$0 67	$7.81	$53.37
2	1.13	....	40.33	2.61	2.80	1.50	.95	7.85	48.19
3	3.60	2.90	97.30	13.87	12.24	2.61	5.10	33.82	131.12
4	1.62	4.13	147.93	9.46	11.62	1.89	2.43	25.40	173.33
5	1.24	1.98	90.47	8.13	6.98	1.94	.75	17.80	108.27
6	5.40	2.13	101.69	5.77	9.24	4.64	1.13	20.78	122.45
7	2.01	.07	23.28	3.71	5.21	.26	.24	9.42	32.70
8	.72	.77	30.14	2 97	5.28	1.16	....	9.41	39.55
9	3.53	....	33.03	13.10	12.78	3.53	....	29.41	62.44
10	10.22	....	137.25	44.10	43 40	1.30	7.80	96.70	233.95
11	1.39	....	86.38	26.41	28.29	1.43	7.07	63.20	149.58
12	.88	.22	2.66	3.40	3 22	1.46	.55	8.63	31.29
13	1.93	2.73	56.94	7.29	9.57	1.19	1.46	19.51	76.45
14	3.59	6.10	123.12	10.79	13 33	2.15	2.15	28.42	151.54
15	1.22	.10	22.56	1.88	3.76	.19	....	5.83	28.39
16	.58	.31	15.19	1.57	2.02	.74	.14	4.47	19.66
17	.21	....	10.19	2.30	2 35	.85	.60	5.50	15.69
18	.27	....	11.73	3.68	3.93	.20	.96	8.77	20.50
19	.56	....	15.67	2.88	2.85	.25	.75	6.73	22.40
20	1.56	....	13.40	2.62	3.21	.22	.58	6.63	20.03
21	.22	....	10.49	2.57	2.96	.16	.54	6.23	16.72
22	3.22	...	15.70	3.04	3.36	.24	1.10	7.74	23.44

COST PER HORSE POWER PER HOUR

No. of Plant	OPERATING EXPENSES						FIXED CHARGES					Cost per horse power
	Fuel	Wages	Supplies	Repairs	Water	Total	Interest	Depreciation	Insurance	Taxes	Total	
1	$.00367	$.00154	$.00024	$.00081	$.00013	$.00640	$.00036	$.00049	$.00015	$.00009	$.00109	$.00749
2	.00316	.00191	.00057	.00016	.....	.00580	.00037	.00040	.00022	.00014	.00113	.00693
3	.00445	.00548	.00122	.00044	.00036	.01195	.00171	.00151	.00032	.00063	.00417	.01613
4	.01594	.02740	.00297	.00053	.00135	.04820	.00308	.00379	.00062	.00079	.00828	.05648
5	.00778	.01376	.00198	.00033	.00053	.02440	.00218	.00188	.00052	.00020	.00478	.02918
6	.00455	.00788	.00068	.00072	.00028	.01361	.00077	.00124	.00062	.00015	.00278	.01641
7	.00296	.00222	.00014	.00051	.00002	.00585	.00092	.00131	.00006	.00006	.00235	.00820
8	.00402	.00216	.00013	.00016	.00017	.00664	.00065	.00116	.00026	......	.00207	.00871
9	.00157	.00148	.00031	.00040	......	.00377	.00149	.00146	.00040	......	.00336	.00713
10	.00441	.00981	.00104	.00123	......	.01650	.00530	.00522	.00015	.00094	.01161	.02811
11	.00303	.00622	.00045	.00016	......	.00986	.00302	.00323	.00016	.00081	.00722	.01708
12	.01276	.00910	.00112	.00094	.00023	.02415	.00362	.00343	.00155	.00058	.00918	.03333
13	.00511	.00532	.00049	.00040	.00057	.01190	.00152	.00199	.00025	.00030	.00406	.01596
14	.00608	.00683	.00109	.00044	.00075	.01520	.00133	.00164	.00020	.00026	.00350	.01868
15	.00281	.00256	.00085	.00036	.00003	.00661	.00055	.00110	.00005	......	.00171	.00832
16	.00178	.00244	.00014	.00018	.00011	.00494	.00051	.00065	.00024	.00005	.00145	.00639
17	.00259	.00062	.00018	.00007	.....	.00345	.00078	.00079	.00008	.00021	.00186	.00531
18	.00292	.00074	.00021	.00009	.....	.00396	.00124	.00133	.00006	.00032	.00295	.00691
19	.00377	.00107	.00027	.00019	......	.00530	.00098	.00096	.00008	.00025	.00227	.00757
20	.00296	.00076	.00028	.00053	.....	.00453	.00089	.00109	.00007	.00019	.00224	.00677
21	.00261	.00085	.00016	.00008	......	.00370	.00091	.00104	.00005	.00020	.00220	.00590
22	.00301	.00076	.00046	.00109	......	.00532	.00103	.00114	.00008	.00037	.00262	.00794

In conclusion, I wish to say that if I may have the assistance of the members, by providing me with data, by next year I can prepare a more helpful paper, going more carefully into the question of calorific value of the different coals used and of the different types of plants.

DISCUSSION

The President: Gentlemen, Mr. Rice's paper is now before you for discussion. The topic for discussion following is, "Prices and Discounts for Electric Currents, and Methods of Billing Current to Customers." The two subjects are so closely related that in discussing Mr. Rice's paper the members should feel at liberty to discuss the question of cost and selling price.

Mr. Scovil: In the beginning of Mr. Rice's paper is the following paragraph:

"In America, the variation in the investment per kilowatt is $200 to $750 per kilowatt-capacity installed. In a few cases the figure is below $200, and in a few as high as $1,000; but in the great majority of cases the cost is below $400." I should like to ask what is meant by the word "investment?"

Mr. Rice: As I understand, the data given, in the literature that I have quoted, cover the entire investment in the development of water-works, if it is a water-works plant, or the steam plant, buildings, real estate, distributing system, whether underground or overhead, to the meter of the installation in the consumer's plant.

Mr. Scovil: Does it cover royalties?

Mr. Rice: So far as I know, it does.

Mr. Ayer: There is a note in the paper where it speaks about the losses or unaccounted watts developed in the lighting station, as compared with gas; the indications are that the losses are from different sources. I ask Mr. Barker his understanding of it. Is it not a fact that the gas losses are due to condensation and leakage, quite as much as the watt losses are due to line losses; in other words, are they not in both cases losses in distribution?

Mr. Rice: I shall have to ask the assistance of some manufacturer of gas.

The President: The question was addressed to Mr. Barker.

Mr. Barker: Mr. President, I think that Mr. Rice has indicated rather more correctly than Mr. Ayer the different causes of line losses in the distribution of gas and electricity. Losses in gas distribution are almost entirely from leakage. The condensation loss, if the gas is properly made, and sent out in proper condition, is reduced to a very slight percentage, and the large losses of which you hear, are due to leaks at the joints or actual breaks in the mains. Where extensive improvements are being made in the streets, whether by use of steam rollers upon the surface, or by construction under ground of sewers, water pipes and electrical or other conduits, the unusual strains imposed upon the pipes are sure to make considerable losses of gas through the opening of the joints and the actual breaking of the pipe itself. The causes of loss in distribution are therefore somewhat different in the supply of gas from those in electric light, although, as the principles governing the distribution of electricity are better understood and more carefully applied, the losses in the electrical supply may be reduced to so low a percentage as to compare favorably with the best results in gas distribution.

MR. COGGSHALL: Is it your theory that the loss in gas is greater than that in electric light?

MR. BARKER: From my observation, I should say that at present the percentage of loss in electrical distribution is much greater than in the distribution of gas.

MR. COGGSHALL: I will state that our loss of output by alternating current from the first of January to the first of April was fifty-three per cent; we collected for forty-seven per cent. I account for it by the fact that the loss largely existed in the transformers. Our day output is small; we run twenty-four hours a day the entire year, and, so far as we can indicate it, the loss in the daytime for about eight hours is equal to twenty-four horse power, without receipts to amount to anything to speak of.

Mr. Wagner: In that connection I would suggest that the losses may be accounted for in the fact that the meters do not register the full amount of the current that is used. From my observation, I should say that those figures are nearly correct for the usual alternating-current stations in small cities. The efficiency of distribution is rarely much over fifty per cent; the loss aggregates nearly fifty per cent. With a direct-current station it is somewhat less.

Mr. Coggshall: I agree with the last speaker in regard to the loss in electric meters. We put in a meter at the Normal school, and found that it took over twenty amperes to make it work at all.

The President: Gentlemen, we are drifting away from the subject in hand. The question of loss in distribution will come up to-morrow. The question now under discussion is the cost and selling price of current; and I should say, in order to be specific, the cost and selling price of the units we produce. The question of the influence of loss on it will come up in to-morrow's discussion.

Mr. Dow: I should like to get a certificate of the accuracy of the statement regarding the Budapest system. It is referred to on page 55 of the paper, and the London *Electrician* is given as the authority. It gives the gross watt-hours per pound of coal as 575 and 571 respectively. It is specifically stated that it is gross watt-hours, and the station is described as a station where the difference between apparent and real watts would be quite considerable. The figures seem almost impossible, but Mr. Rice has no doubt given them careful consideration.

Mr. Ferguson: In connection with what Mr. Dow says as to the figures for the Budapest system, and his doubt of their correctness: The Budapest station pays more for coal than we do, so that the figures 571 are possible, with coal at $4 or $5 a ton. On that basis, if they pay $4 a ton for coal, I think the figures are correct. It costs them more for coal at Budapest than it does at our best American stations. If they pay $3 a ton for coal it costs them more than it does in the best American station.

MR. DOW: With all due respect to the Budapest statements, I do not think they are correct. The main engines alone might accomplish that result; it is possible to get them down to about one and four-tenths pounds of coal; but to get the whole plant down to such a figure, seems to be out of the question. There is a mistake of about two hundred watts.

MR. CREDEN: Some of the figures presented in Mr. Rice's paper are indeed extraordinary, and even the best engines constructed could not produce sufficient steam economy to substantiate such low coal consumption per watt-hour of output. Suppose the highest grade of anthracite coal were used, coal evaporating, say, 11.5 pounds of water from and at 212° Fahrenheit, equivalent, let us say, for sake of argument, to 10.5 pounds, from the usual conditions of feed-water temperature and steam pressure met with in electric light plants; and, further, suppose the engines were of such type of multiple expansion with condensers, with the dynamos direct-connected to the shafts of the engines, and such engines used only twelve pounds of steam per indicated horse-power hour, then the watts produced per pound of coal consumed would not exceed 560. These figures are far more economical than any engines we have in this country will produce, and do not represent the average twenty-four hours' run of an electric-light plant, since no allowances are considered for the consumption of steam in auxiliaries, such as pumps of all kinds used in electric-light stations, nor for the large radiation and condensation losses, which frequently run to twenty-five per cent and more, so that the 560 watt-hours per pound of coal is a very remote figure.

The Chicago-Edison company's Harrison street station, representing the very highest type of electric-light plant, with a load curve such as few stations have, produces a kilowatt-hour at its switchboard from a consumption of about thirty pounds of steam averaged during a day's run of twenty-four hours. If we used the best grade of coal known, we should require, therefore, about *three* pounds of coal per kilowatt-hour, and hence produce about three hundred and fifty watt-hours per pound of coal."

(The president here requested Vice-President Stetson to take the chair.)

MR. INSULL: I have here a chart that shows the average cost of various operations in connection with our operating expenses, and the interest portion of the operating expenses. The columns here show the interest charges with different character of load-factors. I present this to you now, as it is a matter bearing, not only on my own remarks, made a short time since on the question of cost and selling price, but also upon the paper just read. These figures are taken from our actual balance sheet of the year. The largest amount of expense of any particular character is general expense. The reason for this is that one-third of the expense is in getting new business; one-third administrative expenses and the balance insurance, taxes and similar items. For instance, take the question of street repairing; that item will go down continuously as your load increases.

The biggest item of expense, apart from general expense, is lamp renewals, as Mr. Rice indicated when he referred to the question of regulation being more important than the question of economy. This column refers to lamp renewals, and the last one to fuel; the latter being about twenty-five per cent of the former. The important point that the chart brings out is the interest cost. You might have all of your operating expenses presented to you, outside of interest, and then you could lose money; it would be possible to do such a thing if your selling price were not on the right basis. Here is a case of a 3.7 load-factor. It is an office building; an actual case, not an extreme case. I could show you cases where the load-factor would be much poorer than that, but in that case the interest charge is eighty per cent of the total operating charge. Here is a case of an ordinary fancy store—these cases are taken from the actual bills—and you see there that the interest charge is a little less. The importance of the interest charge in this case will be brought home to you when I tell you that the difference between six and five per cent in the price you pay for your money, and whether you sell your bonds at ninety per cent or sell them at par, makes a difference of sixteen to twenty per cent in the cost of operating expenses. That statement alone will show you that the general public is more interested than we are in the question of protecting us in our right to do business.

Now we come to the all-night restaurant, where the load-factor is forty-eight per cent; the interest charge is only twenty-six per cent of the total expenses. These are the two extreme cases I mentioned to you in my opening remarks. In this case [indicating] you could sell current to a man at about a quarter of what you could sell it to this man, and make more money out of the former than out of the latter. You will find that the same relation goes all the way through with the different classes of business. Power business is not quite so good as all-night lighting business; the load-factor is about thirty-five per cent, and the interest expense thirty-two per cent. With a dry-goods store the interest is about forty per cent; with a small lunch counter the interest is forty-five per cent, and with a saloon the interest is fifty-two per cent.

It is generally supposed that the best business is the power business. I remember in the early days, when the rates were established to foster the power business of the Edison Electric Illuminating Company of New York, the claim was made that you could afford to sell power at one-half the price if your current was going to be used for power when it was not going to be used for light. We have found that the power curve and the light curve cross each other for sixty days during the winter, and the claim that was made for the power business has proved a fallacy.

In your lighting business—I am talking to people using large stations—you can get a class of business that will yield you a bigger return on your investment from lighting customers than from power customers at a low rate, because the interest cost, if you have a fifty per cent load factor, is only twenty-five per cent of the total cost; whereas, with power customers the interest is about thirty-five per cent. This chart, properly studied, should enable a man running the Chicago Edison company to make a price list that would fit all kinds of customers. If we can do that in our business, surely you people can do it in your business.

You will find, too, that the adoption of a system of rates that will take care of these different conditions, will affect these items very materially. It will not affect lamp renewals, of course. It will certainly affect station repairs, general supervision, station labor, fuel, and also general expenses. In other words, it will affect by far the greater proportion of your expenses outside of interest charges; besides very materially affecting your interest charges, by putting your revenue on such a basis that it is in proportion to the interest you have to pay to take care of the customer whom you are supplying with current. Your business should be on such a basis that you get a return on the investment that you have to provide for each separate customer. This subject came up for discussion last year, at Niagara Falls. One gentleman, who, I am sorry to say, is not here to-day, took the ground that we had to sell the product at the same price to everybody. If you do, you are selling your product at different prices to everybody, because your cost varies according to conditions. Take, for instance, this case: That office-building customer won't enable you to pay interest and depreciation on the investment. You may have to take him as good business policy, but do not fool yourselves, when you put on 5,000 lights in an office building, that you are going to make any money on them. We do the largest office-building business in the country, and I am perfectly willing to say to you that I do not believe we make any money on it; we take it as a matter of policy. If the expenses of a station are followed out in this way, you can get a great deal more out of the method by which you sell than you can out of the method by which you produce.

Mr. Armstrong: What would you call your standard rate? What would be your base rate?

MR. INSULL: I never expect to sell to that man below twenty cents a kilowatt-hour, unless the conditions of production change.

MR. DE CAMP: Mr. Armstrong means whether you establish a base rate for the least-desirable customer and work down, or whether you take a base rate on the most-desirable customer and work up.

MR. VAN TRUMP: How do you distinguish between your customers?

MR. INSULL: It is simply a question of whether you are going to do it by figuring on lamps connected, which is fallacious, or adopt some scheme that enables you to register the maximum load.

MR. HUBLEY: How can you regulate that plan on a meter basis; different rates for different services?

MR. INSULL: There are various ways of arriving at that.

MR. HUBLEY: I do not see how it could be done on a flat rate, on a contract basis; I do not see how you could do that without a great deal of computation.

MR. INSULL: Do you mean a meter flat rate, or contract basis?

MR. HUBLEY: Contract basis; so much a month.

MR. INSULL: We should go into the hands of a receiver on that basis.

MR. HUBLEY: Do you use meters here under that plan?

MR. INSULL: Yes, sir.

MR. BARKER: You spoke of the different classes of business earning a certain percentage on the investment. How do you apportion the investment among the different classes of business?

MR. INSULL: On our maximum output per year. We take an investment of that kind, and divide the one by the other, and get the investment per unit at the maximum output. Then we get the maximum demand upon us for current from the customer, and in that way we can figure his load-factor. As we know what it costs for our investment per maximum unit of output, and as we know our customer's demand——

MR. HUBLEY: How do you know that?

MR. INSULL: There are a number of ways of arriving at it. You can use a Bristol recording wattmeter, or you can use some kind of indicator that will show it; there are a number of ways. We use the Wright demand meter.

MR. WENDLE: In towns of 25,000 people there are a number of small customers whose maximum demand may not be five lights; they are very desirable customers. What would you do in their case?

MR. INSULL: If your smallest customer is a man that burns one light, and burns it five hours a day, he is likely to buy it at a rate of a little over one-half a cent per lamp-hour.

MR. WENDLE: How small a customer can you afford to take?

MR. INSULL: It depends upon the efficiency of the lamp. If you will give us a twenty-five-watt lamp, we will take a customer whose demand is twenty-five watts.

MR. WENDLE: Can you afford to do that with the Wright demand meter? On what number of lamps do you use the meter?

MR. INSULL: Mr. Ferguson, what customers can we afford to take?

MR. FERGUSON: We take any and every customer on the Wright demand meter basis, and we have a uniform schedule of prices for everybody, based on one cent per lamp per hour; that is the base rate.

We charge the full rate of one cent per lamp per hour for one hour per day, as the maximum demand, and for all watt-hours beyond that hour we charge a half rate, forty or sixty per cent, or anything you please. In regard to the question of what customers you can afford to take, that would involve a great deal of calculation. The simplest way is to charge a minimum bill to each customer, which will cover the smallest customer. If you charge a minimum bill for services furnished, that will cover interest and depreciation charges on the cost of the investment used.

MR. SCOVIL: I should like to know whether the chart that you have shown, and the percentages you gave, do not include a great many motors that are used for electric power, such as elevators?

MR. CREDEN: Yes, it does.

MR. SCOVIL: I simply want to have it understood that Mr. Insull's deductions from his chart, as to the desirability of power as a load-factor on the station, are not altogether to be accepted from the showing made by the chart; for the reason that that chart includes in it many motors used on electric elevators, in which the power factor is very small; that motors used only for manufacturing purposes have a much higher power factor, and are entitled to a much better rate.

MR. INSULL: I do not say that power is not desirable business.

MR. SCOVIL: It is good lighting that is as good as ten-hour motor power, ordinarily.

MR. INSULL: I do not wish you to think that we do not cater for power business. We have nearly 9,000 horse power in motors connected to our circuits.

MR. COGGSHALL: You charge one rate for one hour a day, and another rate for the rest of the day; how do you do it?

Mr. Insull: That is called the two-rate system; it is done by a meter with two dials. I think this subject is the most important one that we can consider; I devote more of my time to it than to any other one subject connected with our business. If you want details on the subject, as we have them in Chicago, we shall be glad to give them to you at our office, or we will answer any further questions. The way you sell the current has more bearing on the cost and profit than whether you have the alternating or direct-current system, or a more economical or less economical steam plant.

Mr. Wagner: I understand from your remarks that the Chicago Edison company is going to use the Wright demand system of charging, which is a very thorough way of providing for all these different classes of service. I should like to know if there is anyone here that accomplishes nearly the same thing by any other method?

Mr. Dow: I have been into this thing up to my neck. I suppose that remark will interest a good many members here from small towns, say of 25,000 inhabitants. We have more than 25,000 people, but we have not money enough to buy Wright demand meters for all our customers just yet; we are going to do so some day. However, we use demand meters on a number of customers; we use them when there is doubt of arriving at the demand by any other means. We do not believe it necessary to leave them on continuously, but we put them on long enough to make certain that we have ascertained the average demand for the current twelve months, and in such cases we take the demand established by meter, and base a contract on it with the customer for the current twelve months. We say to him that he shall pay for that amount at the maximum rate, and everything beyond that at a minimum rate; and at the end of twelve months we will again meter in the same way, and reserve the right to put the meter on at any time, to satisfy ourselves as to what the actual demand is. In some places we leave the meters on continuously. We should do so all the way through but for the one point of not having money enough to put them on everybody.

MR. AYER: I think it would be interesting to the members that did not attend the last convention, when the Wright demand system was described, to have a brief description of it given here by Mr. Dow.

MR. DOW: The Wright demand meter is thus far the most satisfactory method of recording the maximum that a customer takes at any time. The principle is the same as that which governs the registering thermometer. You know the style of thermometer,—which not only shows the present temperature, but which leaves at the highest point it reaches a little globule of colored alcohol, so that anyone, on inspecting the thermometer, can tell, not merely the present temperature, as he can by looking at any other thermometer, but he can also tell to what point the alcoholic column has risen since the thermometer was last set. The setting is accomplished by shaking down the retained globule, and the process of resetting in the Wright meter is the same. The meter is a system of tubes containing a fluid that is expanded by the heat generated by the electric current, and it leaves an indication showing the maximum current that has gone through the instrument since last set; not that the customer has used so many ampere-hours, but that at one time he called for current at the rate of so many amperes. That indicates, of course, the largest amount of machinery you have to install to take care of that customer. There are lots of buildings where there may be four or five hundred lights connected, but never all burning at once, and the number of lights that may be going at any one time is an important factor in cost of supply. What you want to know at the station, is how much machinery you must provide to take care of that man's load. In other words, you want to know what your interest charges will be to provide for that man's business. The Wright demand meter records the largest call that the customer has made upon the station since the last setting.

Now, to answer the question raised, as to how anyone has reached the same result by other means. In the matter of arc lighting, practically nine-tenths of the business is with customers whose "lamps connected" are all turned on at once. If a man has ten arc lights, he is likely to use all at the same time, so that in a majority of cases the number of arc lamps will be an exact measure of the demand. With certain classes of motors the same thing applies; not with all classes, by any means, because there is nothing more frequent than a motor running at a much less load than its rating; the elevator motors, to which Mr. Scovil referred, are an instance. Then, there is a large amount of motor business where you can put on an ammeter occasionally, and ascertain the largest demand. As we are situated now, we have been trying to develop the motor business and inspect motors frequently; and we have not so many that a faithful man cannot visit them all in five weeks, and as we use the ammeter, we are not missing anything; but our method of checking depends on personal knowledge, and can only be looked upon as a makeshift. It does not compare with the Wright method, although as a temporary device it fills the bill. Beyond these, you have still another class of customers: small barber shops, saloons, cigar stores, news stands and fruit stands, that use only a few incandescent lights and keep open long hours. They are good customers, and their demand is practically the same as the number of lamps connected. Finally, there is the general use of incandescent lights, where some meter must be used. We use the Wright meter on these customers.

If there is any place where a demand meter is a good thing, it is in a residence. You know how residence-lighting bills vary. You have the man that says: " I have a great many rooms in my house, and you have sized it up and made the bill accordingly. I have only three persons in the house, and this bill is big enough for ten." The demand meter stops the talk, and shows that he turned on so many lights at one time. There is the other man, who burns only five or six lights from dusk until ten or eleven o'clock at night. He is a good customer, and the demand meter gives him all he is entitled to. The only objection to the demand meter is from the man that has a great deal of decorative lighting. We have houses where, out of 200 lights connected, there are 100 decorative lights. They are burned only occasionally, and something must be done to encourage the use of these lights without raising the indicated demand too much. Mr. Wright turns off the demand meter for this kind of customer when the customer gives notice of an entertainment that will use the decorative lights.

We expect to use the Wright demand meter all through our residence business. In the meantime, as a makeshift, I have assessed each house according to its size—assessed it for the "demand," I mean—to give the amount that will be charged for at the maximum rate before the second rate applies. A customer pays the water rate that way and house rent that way; and, while the system as applied to lighting may not be perfect, still, it will serve the purpose for a while; and when the man with three in family complains of a high assessed "demand," and points to the smallness of the family, I tell him that I regret that his family is so small, but that I am not prepared to give him advice as to how to increase it.

I find the method of the high base rate and the small second rate to work very equitably indeed, and we have found a gratifying increase in power, arc lighting and incandescent lighting among the small customers, who are usually desirable, from the application of the method. Our base rate is sixteen cents per kilowatt-hour. It should be higher for office buildings, and such; twenty cents would let us out. The second rate is five cents. The result is excellent, and I can recommend that way of making rates as being a good one, even when you know what a man is going to use. When you charge a customer for 365 hours at sixteen cents, and all the rest at five cents, even though the business would foot up just the same at an average rate of six cents, it is a better policy than to give the customer a rate of six cents to begin with. If you put him on the six-cent rate and he is economically minded, he will try to save money by cutting off the lights when the rate is six cents an hour all through; but in the other way he regards the five-cent light as very cheap, and will burn a good deal of it.

Mr. Wagner: How do you arrive at the assessment on residences, which you spoke of?

MR. DOW: We arrived at it in this way: We considered that many of our residence customers used gas in servants' rooms, pantries, laundries, basements and back halls. These same customers used electric light in their parlors, dining rooms and family and guest chambers. We thought it best that the servants' rooms, etc., should not be taken into account in assessing the premises. So we prepared a blank, in which the rooms were listed in two columns: parlors, etc., in the first column; servants' rooms, etc., in the second column; and we premised that the demand in any house ought to be proportional to the number of rooms in the first column. Then we made a thorough canvass of all our customers in a representative residence district, ascertained the distribution of their rooms, and compared the figures obtained with their bills for the past twelve months. We arrived at the conclusion—after taking into account our standing charges and running charges—that the figure for each room in the first column, to be paid for at the maximum rate, should be three units per month. Thus, a man that had a ten- or twelve-room residence gets six or seven rooms—say six rooms—listed in the first column, and he is charged at the high rate for six times three, equal to eighteen units of supply, on each monthly bill, at the maximum rate of sixteen cents per unit; and for all current used in excess of eighteen units, at the maximum rate of five cents per unit.

It is too early as yet to say that the application of the demand system to the residence business is a success, but the first results are good. In many cases where gas was formerly burned excepting in a few rooms, electric light is being used throughout the house. One very good symptom is that electricity is being used more freely in servants' rooms. We think that the winter season will show a decided increase in our output.

MR. WAGNER: Does not that complicate the system of billing?

MR. DOW: We bill units in all cases; the form has a blank line for units at base rate of sixteen cents, and another line for units at second rate of five cents. On the meter blank, the base is marked in red—eighteen units at sixteen cents, equal to so many dollars and cents.

MR. WAGNER: You have to collect all the data for each customer?

MR. DOW: With the residence customers only.

MR. WAGNER: We have 75,000 incandescent lamps in residences alone in St. Louis.

MR. DOW: We have 21,000. I do not know of any other way of doing it. After you once do it you have it; it is part of the record.

MR. ROBERTSON: In formulating a scheme for the adoption of the Wright demand system, I found a certain class of business that I did not know how to handle; it comes from lodges, churches, etc.

MR. DOW: Mr. Wright maintains strongly that the relation of the annual station demand and customer's demand to the time at which the demand takes place, is of no consequence; but I feel that it is, so I have reclassified all these certain lines of business, which include these troublesome customers mentioned, who think that they ought to have special rules. I have churches, lodges, schools, banks, on special rates. Our annual peak is due to the sixty days' crossing of meter and lighting loads. The banks are off before the great bulk of business comes on. I established for them, on the same set of calculations, a rate that is equitable, and that is known as the church, bank or lodge rate. It is got at in the same way.

MR. WAGNER: I think we might hear more about the details of the system of the Chicago Edison company.

MR. FERGUSON: Mr. Dow made the statement that he could not afford to buy demand meters; that he would do it after a while, but cannot afford to do it now. After listening to what he said I think he is much mistaken; I think he is spending too much of his valuable time in attempting to understand the personal characteristics of his customers. I am sure that if he does that properly, if he ascertains the characteristics of his customers so well that he can approach the work done by the Wright demand meter, he must employ a large force of assistants; and when we consider that the cost of demand meters is small in proportion to the total investment, and consider the immense amount of business that can be obtained by using them, I think he can well afford to buy them. We will suppose that in Chicago we have 5,000 customers, and that the cost of the instruments would be something like $50,000 for all these customers. We should not spend the entire sum in one year; it would take some time. Our business has improved largely by the use of these meters, and we cannot get instruments fast enough. We have made contracts on the Wright demand basis, and a month has passed and we have not the meters installed in all places yet. It seems to me that any central-station man can well afford to borrow the money, even at a very high rate of interest, as Mr. Ayer has just suggested, and purchase the meters. The additional business that can be obtained by the use of such instruments will, in a few years, more than compensate for the total investment, by having an instrument to measure the current properly. We have listened in these conventions to papers showing the economy to be effected in generation, distribution and that sort of thing. It seems to me that there is more money to be made in the intelligent selling of your product than in attempting to introduce further economies in operation. With an instrument like the Wright demand meter you are put in a position where the instrument does for you what you would otherwise have to do by skilled labor at a very high cost. I say this from experience. For three years I have personally negotiated contracts for the Chicago Edison company on a basis similar to that described by Mr. Dow. I have had customers come in to the office, have talked with them to ascertain the conditions under which they burned their light, and have made prices, with fifteen, twenty-five, and even up to sixty-five and seventy-five per cent discount, depending on the conditions under which they used the light. Since we have put in the Wright demand system the work is lessened, and I am able to give my attention to other things and let the meter do the work for me. There are other methods, of course, of getting at the information, and we have used them. We have used, for instance, the Bristol recording ammeter, which is useful for ascertaining the maximum load in any customer's premises. It is a slow process, and can only be used in large installations, like hotels and theatres, where you desire to make a uniform discount for the entire year, which is practically the same as selling current on the Wright demand system. It is the real load-factor system, as it is the only system based on the load-factor. If you know by the Bristol recording instrument that the load-factor is fifty per cent you can make the rate for the entire year at a uniform discount, which is the same as putting in the Wright demand instrument. It is tedious, however, and much more expensive than buying the instruments and asking them to do the work for you.

In further reference to this question of dealing individually with customers, especially in residences, upon which Mr. Dow dwelt particularly, the load-factor varies greatly, and you cannot classify residences; it is almost impossible to do so. We may, for instance, have a man that has 200 lights in his house at $25 a month, and have another man with twenty-five lights, whose bill is $20 a month. The latter would be entitled to a twenty-five per cent discount on the basis of twenty cents per kilowatt-hour for the first hour and ten cents per kilowatt-hour for the succeeding hours. The load-factor would be over twenty per cent. Theatres use the light for short periods, and the load-factor is small. Hotels are about fifty per cent; large dry-goods houses fifty per cent, and residences vary all over the line. We have not yet published the fact that we are selling electric light on the Wright demand basis; we have, however, instructed our men to take all new business on that basis. We sell direct-current arc lamps at a flat price per week from dusk to midnight. With the exception of that and the power business, it is all done on the Wright demand basis. We put our arc light and incandescent light on the same meter. The reading of the demand meter is made at the same time as the reading of the wattmeter. The wattmeter is placed on the wall, and the demand meter under it. The latter is graduated in kilowatt-hours, the same as the wattmeter.

You take here the reading of the wattmeter, 5,000, and here the Wright demand meter is 2,000. The customary basis for the 2,000 kilowatt-hours is twenty cents, and ten cents for 3,000 kilowatt-hours. The reading of the demand meter is very simple. I have a graded scale taken from a Wright demand meter that we use, showing the gradations of it. The basis on which we charge is a combination of the Wright demand and the two-rate systems. We charge at a certain rate in winter and at a different rate in summer. For the six months in winter we charge twenty cents per thousand watt-hours for the first hour and one-half of daily use, and ten cents for the balance; and in summer time we charge twenty cents per thousand watt-hours for first half-hour's daily use, and ten cents for the balance. I know that it is customary to divide the year into four parts, and take the average of the maximum output. With the American method of doing business, that is impossible; we cannot wait three months for our money. Instead of that, we take the nearest approach to it. It is not absolutely and scientifically correct, but we record the maximum in each individual month, and we let each individual month stand by itself, and make our calculations on the basis of the maximum in each of the six months, beginning with April, and charge the full rate for the first half-hour's use, and in the other months the full rate for the first hour and one-half of use, and the scale is graduated.

(Mr. Ferguson then drew the following diagram, and said:)

The left-hand column is the winter scale; the right-hand column is the summer scale. Our real object in charging at a lower rate in summer than in winter is to induce people to use the service during a time

Kilowatt-Hours Winter	Kilowatt-Hours Summer
600	200
400	133
200	66
100	33
50	16⅔

when our machinery is lying idle. The maximum load is in winter, and during the summer there is a great deal of idle machinery. We get people to use more light and power in the summer.

In a supposititious case, we will say, a man takes 5,000 kilowatt-hours at the full rate of twenty cents, which will be $1,000, and 3,000 kilowatt-hours at half rate, $300; his bill will be $1,300.

Mr. Insull: Is that on the basis of low maximum?

Mr. Ferguson: Reversing it. Suppose the wattmeter showed 5,000 lamp-hours, and this instrument showed that the watt consumption at the high rate was 6,000, then his bill would be $50, because he ought to pay a higher rate than a cent a lamp-hour, for the reason that the demand meter has registered 6,000 lamp-hours.

Suppose his maximum here were only 500 and his total consumption 6,000 lamp-hours; then he would pay $5 for the 500 lamp-hours, and $22.50 for the remainder, and his bill would be $27.50, which is forty-five per cent discount. The customer should use his service about ten hours a day on that basis. You can make the rate anything you please: Twenty cents for the first hour and eight cents for the remainder; or six cents, four cents, three cents, or whatever you choose; that is simply a matter for each individual city.

Mr. Robertson: Do you take into account the maximum demand coming at one time in one case and at another time in another case?

The President: You will find that the average maxima of your customers is about one-third higher than the maximum of your station.

Mr. Ferguson: The sum of the customers' maxima is one and one-fourth times the absolute maximum of the station. I neglected those cases that Mr. Robertson asks about, because they are not worth bothering about. I brought that question up with Mr. Wright at the convention last year at Niagara Falls, and showed him that if a man used his service from four o'clock until twelve he ought to have a lower rate; but the number of customers in this class is so small that it does not affect the system. You must not discredit the system because you have some few customers that want to be treated on a special basis.

Mr. Robertson: It is in the company's favor to disregard it.

Mr. Weeks: There have been few discussions before this association, Mr. President, of greater importance to central-station interests than that to which we have just listened. In the cost of our product, the relative value of the interest factor has been forcibly and clearly shown, and the necessity for revision of rates or discounts has been ably demonstrated. In my judgment, the method employed by Mr. Insull, or a slight modification of it, will soon come into general use. In one respect, however, the practice as stated strikes me of questionable equity, if not expediency, and I should like to ask Mr. Insull what has been the effect upon your revenue of the lowe rates for summer service?

MR. INSULL: We do not know yet; we have only put them in operation during the last few months.

MR. WEEKS: It seems to me that it is somewhat inequitable to make a lower rate for transient summer service, such as that of the customer that operates a fan but a few weeks or months, at most, in the year, while his rate on account of the interest factor should be higher, rather than lower, than that for most other classes of service.

MR. INSULL: That is a discrepancy, but we have a large by-product that we want to sell, which usually lies idle in the summer; and we endeavor to dispose of if to these casual users.

MR. WEEKS: What would be the effect of this system or the Wright system upon the present rates for municipal lighting? What would be the rate on municipal lighting?

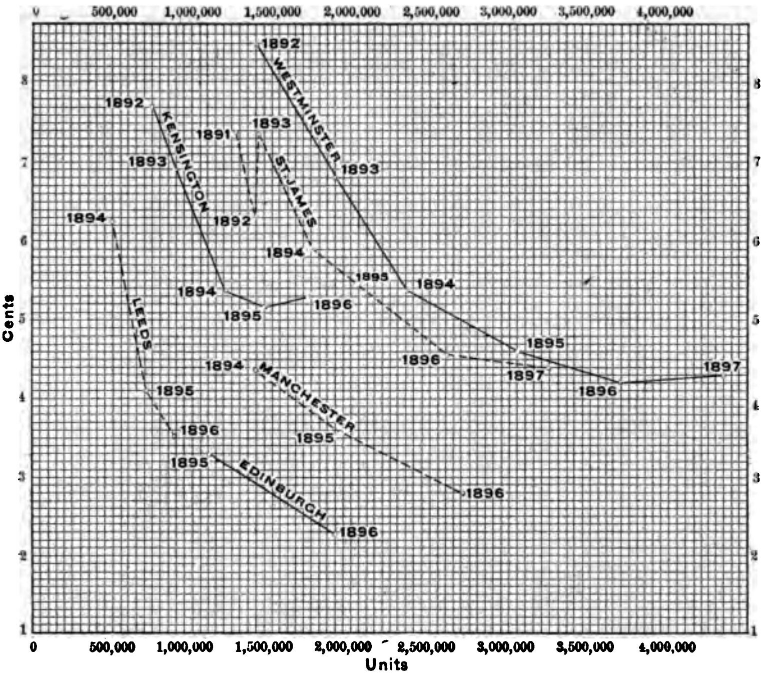
MR. INSULL: It would be very low.

MR. WEEKS: Have you determined that?

MR. FERGUSON: The municipal light runs about twelve hours It depends upon whether it is a moonlight schedule or an all-night service. It would not get so low as you are selling it now. You can readily see that if you make the rate twenty cents for the first hour and ten cents for everything after that, the maximum discount will not reach fifty per cent. It is something higher than that now. It is the same as if you figure ten cents per kilowatt-hour. You will have to make the second rate low enough to figure out the same kilowatt-hour that you are now charging for the arc-light service. That must be arranged in each individual city.

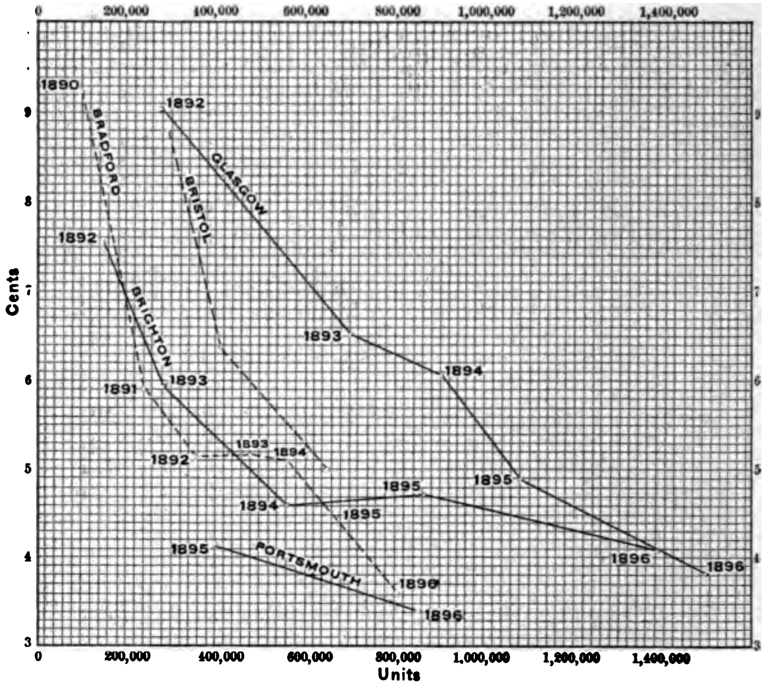
THE PRESIDENT: We should be pleased to hear from Mr. Rice, if he has anything further to say on the subject.

Mr. Rice: There is one point of which I wish to speak. These curves of costs of plants show the figures during the last four years of the "record" plants of England. These curves show plants having outputs of between 500,000 and 4,000,000 units. It



is interesting to observe that the largest plant shown, the Westminster plant, is only about one-quarter as large as that of the Edison company of Chicago. The cost was eight cents per kilowatt-hour in 1890; in 1897 it had dropped to a little over four cents. The smaller plants have, perhaps, one-hundred-kilowatt capacity. Their costs in 1890 were about nine cents a kilowatt-hour and in 1896 four cents; the Portsmouth plant, having a maximum output of 800,000 units only, is down to three and one-half cents, whereas the record of the largest plant in England is four and one-fourth cents per kilowatt-hour.

Mr. Ferguson: This method should be carried



further, and is to be carried further. You can readily appreciate that fifty per cent discount, or ten cents per thousand watt-hours, is not low enough to get all the business. To take out isolated plants, you will have to sell current at five cents an hour, and perhaps as low as four cents. To take care of the large business, it will be necessary to give a quantity discount beyond the discount that you give by the combination of the high and low rate. But that wholesale discount should be based only on that portion of the current that is sold at the low rate; you should not discount the high-rate portion, but only the low-rate portion. The high-rate portion is intended to cover the interest charges, and if you had a customer that had 10,000 lamps and was billed $2,000 under the Wright demand system he would be entitled to ten per cent or fifteen per cent discount; whereas if you gave him discount for quantity, it would be forty per cent, which would be unfair to the small customer. The intention is to give the low rate to the long-hour burner.

On motion, the meeting adjourned until three o'clock.

SECOND SESSION

President Insull called the meeting to order at three o'clock, and announced the first business to be a paper on public lighting with relation to public ownership or control, by Mr. Alex Dow, of Detroit, Mich.

Mr. Dow presented the following paper:

PUBLIC LIGHTING IN RELATION TO PUBLIC OWNERSHIP AND OPERATION

This paper is written to set before the association a proposed policy. It is not a new policy in its parts; neither is it an untried policy. It is applicable immediately to public lighting; that is to say, to the lighting of streets and public places under contract with, or on account of, a municipality. Ultimately, its application may be more extensive.

It is the belief of many members that the National Electric Light Association should formulate and publish a well-considered method of dealing with this business. While local conditions differ, there is no local difference in the principles that should govern electric-lighting companies in their dealings with municipalities and municipalities in their dealings with electric-lighting companies. An authoritative statement of these principles is needed. A statement by the association may be accepted in the first place only by the electric-lighting companies, but if the principles so stated are intrinsically correct, their acceptance by the municipalities must follow. No city government will persist in a course that is plainly inequitable. City governments have in certain cases acted inequitably in the matter of public lighting, but their action has not been plainly inequitable. In such cases, principles have been obscured by details or by personalities, or have been distinctly understood only by the parties on both sides of the case. The public does not seek to be served at the expense of the individual. Public opinion may at times be biased, but it intends and endeavors to be just; and under our scheme of government public opinion is the final authority, and an appeal to public opinion is the ultimate means of redress for any grievance.

The advocates of municipal ownership have long recognized the value of public opinion, and have presented their case, both to the people of the country at large and to the citizens of selected municipalities, through magazine articles, newspaper discussions and addresses to public gatherings. Some of our members have met these arguments in kind, and have confuted extravagant statements by the presentation of facts. But the man who is plainly arguing in his own interest is handicapped in a debate before a non-judicial tribunal as against those who claim to be disinterested. And it is not to be denied that the arguments which have had most influence on public opinion in this matter, are those of theorists, who certainly believe that they are doing the world a service, who are usually misinformed, always impracticable, but thoroughly in earnest.

A declaration of principles by this association, and the recommendation to its members of a policy based on those principles, would have greater weight with the public than the statements of individual companies, and would be accepted as authoritative over a wider area. But even if not accepted by the public, its immediate acceptance by our own members will be useful. That each member must act for himself is a consequence of the conditions of our business; but that all should act on similar lines is possible and is desirable. Each of us looks to other cities than his own for light on problems that are new to him. Each of us, by a successful solution of any problems, benefits the industry at large, and on the other hand, he who fails to appreciate and to properly deal with such a problem as this, injures, by his failure, not only himself, but all of us. Therefore it is well that we should agree on general principles, and that we should advise with one another on special cases.

Let me make this general statement more specific. The member of this association who, by good service, by close figuring of expenses and of profits, and by clear statements and logical arguments, convinces the authorities of his own city that it is to their interest to leave their public lighting in his care has done all of us a service. The member who, on the other hand, fails to recognize the drift of opinion among his fellow citizens, who tries to convince them that unsteady and uncertain lights are worth a high price, who depends for the retention of his city-lighting contract on an appeal to the technicalities of his state law, or to the pockets of the venal members of his local Board of Aldermen,. and who thereby brings about the erection of a municipally-owned electric-lighting plant and the publication of the bare running costs of that plant in parallel columns to the prices which he wished to charge,—the member who does these things that he ought not to do, and leaves undone those other things that he ought to have done, is a detriment to the industry throughout the entire Union.

I have indicated why I believe that a declaration of principles and of policy is desirable. The principles to be declared will need little discussion, but the policy that to me appears best may, when examined by others, appear to require amendment, or even radical change. It is offered to you for consideration in the belief that it is logical and that it is practical; but as a proposition for discussion and amendment, rather than as a perfected plan.

A CHAPTER OF ELECTRIC-LIGHT HISTORY

In the history of street lighting by electricity, no chapter contains more profitable matter for study or for illustration of general principles than that which contains the record of the city of Detroit. That city was one of the first to use electric lights on its streets. It began in 1883 with twenty-two arcs, and in 1884 abandoned all other street lights. This street-lighting business was believed by those who first engaged in it to be a monopoly secured by patent rights; they found their mistake after much money had been invested under that belief; competition ensued; then consolidation, and finally municipalization of the service. I shall find it convenient to refer to Detroit for more than one modern instance.

In February, 1896, the city of Detroit owned 1,500 arc lamps and was operating 1,492 of these in the work of street lighting. In the same month the successor of the Brush Electric Light Company, which installed the original twenty-two lamps in 1883, and which, until 1890, lighted the streets under contract, owned 1,049 arc lamps, and used in private lighting 433 of that number. Another company, organized in 1890 to compete with the Brush Electric Light Company, owned 1,330 arc lamps and was using in private lighting thirty-eight of these. In each case there accompanied the arc lamps a sufficient number of dynamos, engines, boilers, etc., and a building fully equipped for the operation of the number of lamps stated. At the same time the city had in use 134 towers, which had been formerly owned by the Brush company, and the other company was in the act of taking down and removing from the streets 104 similar towers, which had formed a duplicate of the Brush company's equipment. The necessary lines to connect lamps distributed over a large city, had been owned by all three. The city had in use 329 miles of overhead wires, connecting to its 1,492 lamps. Neither of the companies had owned such a great mileage of line, but one had taken down lines and poles that had supplied 719 lamps, and the other was in the act of removing lines and poles that had connected in 1,279 lamps.

Some of the Brush company's street-lighting equipment had been during the preceding five years diverted to the supply of commercial lights. Nevertheless, two-thirds of that equipment is to the present day a useless asset. Lamps that were bought at $40 have proved impossible of sale at one-tenth of the price. Dynamos that cost $2,400 cannot be sold to-day for $240 Lines taken down returned only a small percentage of their cost to the treasury. The towers which this company sold to the city did not bring their original price—that goes without saying—but they brought a fair price.

The loss of the second company was greater. Changes in the business had made their street-lighting arc lamps unavailable for commercial use, or almost entirely so. Similar changes had made their dynamos a slow asset. The engines were partially diverted into commercial service and the boilers entirely so. The wire taken down was not of a size that would fit in to their commercial-lighting system, and the poles hardly paid for the labor required for their removal. The 104 towers—one of the heaviest of all the original expenses—had to be sold as scrap iron.

It is clear that a loss to some person or persons was involved in conditions which reduced machinery and lines capable of supplying over 2,000 arc lamps to approximately their junk value. Leaving out all questions as to personal fault—neither affirming nor denying that the loss fell upon those for whose economic blunders it was the inevitable punishment—it is certain that there was a loss to the community at large; that property which might have been, and which had been, capable of doing good service to the public, was as surely destroyed as if it had been swept out of existence in a great fire.

It may be asked, on whom did the loss fall? In social economy the loss of one is the loss of all, but to our customary modes of thought there appears a difference between losses borne by ourselves immediately and those which are apparently borne by other people. In this case, the greater part of the loss was borne by business men of the city of Detroit. It was a reduction of the available capital of men engaged in productive industry in the city. This reduction—this absolute loss—after correcting for inflated values that should have been written off long before the period of liquidation; after correcting for securities issued for cash at less than their face value, or for considerations that were valued at more than their true worth, was not much less than $400,000.

I do not ask you to sympathize with the immediate losers, but I ask you to remember as my argument proceeds that this loss came about in consequence of business methods and of social tendencies that are in active operation to-day in nearly every town represented in this association. And I submit, as a principle not admitting of dispute, that the duplication of an effective equipment for public lighting is an economic error, entailing loss of available capital to the extent of the duplication.

IMPROPER COMPETITION

The first error in Detroit was the offer to the city of competition for the public-lighting contract. The men that made the offer knew perfectly that their success would mean a heavy loss to the original contractors, but they were willing to make a profit through other people's losses. In this they disregarded a principle much older than the electric-lighting business—that which calls on us to do to others as we would that others should do to us. Some of these men doubtless thought that they were doing the city a service by providing competition, but the managers of the manufacturing concern which was the majority stockholder and chief promoter in the new organization, had no such excuse. Their object was to sell machinery. I do not ask you to condemn these people now. They have reaped as they sowed, and the exploitation of competing lighting companies by manufacturing concerns is a thing of the past, although its consequences in the shape of inflated capital are likely to be a burden for years to come.

I submit, as a direct application of the principle last stated, that competition for public-lighting contracts, for the execution of which there is already an effective equipment in existence, is not legitimate business. The corollary of this statement is that the price at which public lighting is to be performed must be determined by some acceptable means other than competitive bidding. In this there is a departure from the established method of municipalities, which

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now depend on competition for the setting of prices on all public services performed by contract.

WANTED: A SUBSTITUTE FOR COMPETITION

In the absence of some other acceptable means of setting a proper price for public lighting by contract, public opinion will not tolerate the suppression of competition. A reference to Detroit illustrates this very well. When the second company had, by making a lower price and by meeting the demand of the public for the undergrounding of wires in the business district, secured a three-year contract for public lighting, its managers found themselves in a precarious position. It was apparent that at the term of the contract they would again have to reduce prices to meet the competition of the original contractor, who could not afford to have his plant standing idle. It was also immediately apparent that the idle plant would be, as far as possible, diverted into private-lighting work and would there also tend to reduce prices and to divide the available business. Legal questions as to patent rights added to the difficulty of the situation. An attempt to combine the two interests was plainly necessary, and it was made; but the inevitable personal soreness prevented a combination until the new company had completely duplicated the equipment of the old one.

Of course the public became advised of the cessation of competition, and the advocates of municipal ownership made the most of the facts and added much fiction. Long before the contract had expired it was plain to any careful observer that it could not be renewed at anything like the former figure, and that the tendency of public opinion was strongly to municipal ownership. It was a period of "reform,"—I use the word in its political sense—one of those periods when the taxpayers, usually content to be bossed unquestioningly by the practical politicians, insist on calling the particular bosses of the hour to an accounting, and expect to find that they are rascals. And as the public's way of having an accounting is to discharge its servant first and take up the reckoning afterward, the public servants of such periods are quick to fall in with the drift of public opinion, in order to show that they either do not deserve discharge or are fully justifying their appointment to their new situations. Politicians are wise at such times; lighting companies are sometimes very foolish.

So the cry went up that there was no such thing as competition in the lighting business; that the men engaged in that business all intended to rob the public, and that if they appeared at times to compete with one another it was only a temporary falling out among rogues. And the public being told on the one hand that all existing lighting companies were composed of rascals, and on the other that all municipally-owned plants were successes, made up its mind that its only salvation lay in municipal ownership.

You can see, and any careful student can see, that the suppression of competition was inevitable, because its continuation meant a cumulative loss to those engaged in it. Possibly the public might have been made to see this, although the time to have begun work on the public was before the first loss due to competition had been incurred. But merely to prove that competition was impossible, would not have been enough. It must further be proved that competition was unnecessary, and the only way to do that was to offer good service at an acceptable price. Under the circumstances the price might have to be very low indeed, for the belief was abroad that the business was enormously profitable at the established rates. The figures sent forth by certain municipal plants were quoted as warranting this belief, but these could have been contradicted. It was possible to send to Bay City and to Topeka a competent engineer—say one of the professors of the University of Michigan—whose dictum would be accepted by the newspapers and their readers, and so to obtain the true figures. It was possible to answer in a similar manner the argument based on the competing bid at the last letting of the contract. That argument was that any business which justified the erection of a complete manufacturing plant on the security of a three-year contract, must be exceedingly profitable. The contract price was a good one, but it would not pay for the plant in three years, as the public of Detroit thought it would. A showing of the whole truth as to costs, certified by a recognized authority, and followed by a bid carrying a minimum profit, might have been accepted by the public as a substitute for competition.

A COLLISION WITH PUBLIC OPINION

And here was made the second great error of the electric-light companies. Their managers seem to have been the only people who did not see what was coming. They failed to keep in touch with their public. The public was absorbing all the fool figures that the wildest theorists could furnish, but never a figure deserving credence was offered in contradiction. The public was damning the poor quality of the lights then furnished, and was told that it did not know a good light when it saw it. The public was determined to have much cheaper lighting, yet when bids were asked for they were almost as far above a possible figure as the costs published by the theorists were below it. The only hope for the contractors was to secure the support of the more conservative elements by offering good light at a minimum rate. On their failure to do this, and do it quickly and gracefully, municipal ownership was as certain as the coming of summer.

Some effort was made by the companies in the legislature of the state and in the city council to protect their interests, but these bodies, especially in a reform year, cannot be expected to go counter to a strong public sentiment. In this they are wise in their generation.

Would the public of Detroit, after the agitation for municipal ownership had become general, have approved of award of a contract at a low price, or would it have insisted on municipal ownership as a matter of principle?

An answer to this is merely an expression of opinion, but I believe that had a low price been offered, the agitation for municipal ownership would have been suspended, and the companies might have secured terms more to their interest than was the action actually taken. There were many people in Detroit who did not wish to see the experiment of municipal ownership tried, except as a last resort. There were a few people who believed in municipal ownership as a matter of principle. There were, doubtless, also a few who expected to reap a personal benefit from the establishment of the city plant. Nevertheless, the great majority of the citizens sought only to reduce the expense and to improve the quality of the public lighting, and cared nothing for city ownership except as a means of reaching a desired end.

In other lake cities, where the agitation was fully as strong, concessions on the part of the lighting company led to a continuation of the contract system. The case of Toronto is a notable one, because the municipal sentiment is exceptionally well developed there. The local company is now performing lighting for the city at a figure a trifle less than was estimated as the cost of operation of a city plant. At Cleveland the local company holds the business because it made a price so near to actual cost that there could be no possible saving in municipal ownership, and the price was accepted after a careful inquiry into costs in neighboring cities on behalf of the municipality. The recent case of Tonawanda is another instance of success won on the same lines. There, the local company submitted figures made by a recognized authority, showing the actual costs of operation in several representative municipal plants, and followed these figures by a bid more favorable to the city than municipal operation. I am assured that in each of these cities, while the contract figures are low, the management of the local company considers the business ultimately, if not directly, profitable.

THE REASON FOR PUBLIC LIGHTING BY CONTRACT

In these instances the local companies have retained their public-lighting business by demonstrating that it was to the interest of the municipality to let them retain it. In this they have put into sucessful practice the most important part of the policy which I advocate. I submit that the only sufficient reason why a municipality should contract with a private company for public lighting, is that the private company can do the work, and is willing to do it, cheaper than the municipality can itself do it by the direct operation of a public-lighting plant. It is in order to show how this comes about.

A DIFFERENCE BETWEEN PUBLIC LIGHTING AND PRIVATE LIGHTING

There is no longer any question of the right of a municipality to own and operate its own public-lighting plant. Electric street lighting is a distinctly public service, which must be provided for by the municipality. It is a service to every citizen; is a sequence of the social conditions that constitute city life as distinguished from rural life, and can be effectively performed only on municipal account and under municipal control. Herein it differs from the electric lighting of private premises, and it is necessary to note the difference. Electric lighting is the cheapest as well as the best light for streets and public places. For private premises, on the contrary, electric light is not a cheap light under usual conditions It is not now, and is not likely to become, an illuminant of universal use, to the exclusion of gas and oil. Why this is necessarily so, is well known to the members of the association. To the general public it is a statement better proved by a couple of good examples than by a long statement of causes. In the city of Detroit there were, in 1897, according to the annual report of the water board, 52,219 supply connections to the city water mains and the "families" in the city were 54,945. Each "family" was certainly a user of artificial light of some kind. Illuminating gas of eighteen-candle-power quality is sold in the city of Detroit at $1 per thousand cubic feet. The maximum price charged by the electric-lighting companies for incandescent lighting is 14.4 per kilowatt-hour, including renewals of incandescent lamps; the minimum is four cents, and the system of charging makes the average price 10.8 cents per kilowatt-hour, which, allowing for difference in candle power, is equivalent to gas at $1.21½ per thousand cubic feet on the average, or to gas at $1.62 to the customer whose individual load-factor obliges him to pay the maximum price. These are comparatively low prices, both for gas and electricity. Under these circumstances there are in the city of Detroit approximately 18,000 (?) customers for illuminating gas, and 4,000 customers for incandescent electric light. What light do the remaining three-fifths of the possible customers use? It is safe to say that they use kerosene oil. It is also safe to say that there are very few cases where oil is used merely because gas or electricity is not available. The main cause of the use of oil is its lower cost. I need not say to this audience, although I have found it necessary to make the statement to other audiences that were entitled to be considered intelligent, that there is not the least likelihood of the production costs of kerosene oil, of gas and of electric light materially changing their ratios to one another. As to their selling prices, I think that the Standard Oil Company is better satisfied with the profit which it makes on the sale of kerosene in Detroit than are either the Detroit Gas Company or the electric-light companies in that city with their profits.

I submit, however, a second example of the relative cheapness of gas and electricity, from which example the question of profit is eliminated. The city of Glasgow, Scotland, owns and operates its gas works, and owns and operates its electric-lighting plant. Neither of them is intended to make a profit. I have in my possession signed communications from the managers of each department in which it is written that the price of gas is two shillings and twopence per thousand cubic feet, and that the price of electricity for incandescent lighting (not including renewals of incandescent lamps) is sixpence per kilowatt-hour for the first hour's use of the demand, according to a Wright meter, and two and one-half pence per kilowatt-hour thereafter. Making the same corrections as in the Detroit calculation, and assuming that the incandescent lamps paid for as "extras" in Glasgow are as efficient as those furnished free by the Edison Illuminating Company of Detroit, the Glasgow price for gas is fifty-two cents per thousand, and the Glasgow price for incandescent lighting is equivalent to gas at $1.35 at the maximum rate, and fifty-six and one-fourth cents at the minimum rate. The average is about the same as the Detroit average. I think this example from a city where municipal ownership has been most thoroughly exploited, and where the municipal management is above suspicion of inefficiency or corruption, proves beyond question that electric lighting for private use is a luxury, and, as such, must continue to be used only by those who can afford luxuries; that is to say, by a minority of the citizens of any municipality; not by a majority, much less by every citizen.

Therefore, while it is admitted that the lighting of the streets is truly a public service, which may be performed by the municipality for and on behalf of every citizen, the furnishing of electric light to private consumers is not a public service, but is essentially a service to a few individuals, and, as such, should not be undertaken by a municipality whose object is to perform only those duties that municipal society as a whole owes to itself as a whole. This principle should be clearly understood, and should be boldly maintained. It is necessary that a municipality shall undertake certain services, and it is possible that it may undertake others; but the propriety of its undertaking any service depends on whether that service is to the public or to individuals; to the many or only to the favored few.

THE POSSIBILITY OF LOW CONTRACT PRICES

This leaves to private enterprise the supply of electric light to private consumers. In performing this service there will be built and equipped a power house; there will be organized an operating and a managing force; there will be constructed lines of distribution. All of these may be, and part of them certainly will be, adapted to the performance of public lighting, in addition to the service of private consumers. To whatever extent this double adaptability exists in the private plant, there will be duplication of equipment in any other plant separately established for performance of the public work. Moreover, it is peculiarly characteristic of public lighting operated all night that in addition to the ordinary work of a private-lighting plant tends to reduce the average cost of the combined output. In these considerations rests the possibility of a contractor profitably performing public lighting for a city at or below the price at which the city can itself do the work, and its yet being to the interest of the contractor to undertake the business.

Let us for a minute assume that municipal engineering and management and municipal financiering can be just as good as private engineering and private financiering. If they are not so, it is the fault of the municipality, because technical and financial skill and executive ability are for sale in the labor market, and are purchasable by a municipality, even as they are by private employers. There remains only one evident cause that should tend to make the cost of a municipal plant differ from that owned by an individual or a company. That difference is that the individual proposes to make a profit and the municipality does not. Looking closer at the facts we find that the municipality must in most cases allow the equivalent to a profit, because a municipal plant is built by money borrowed at interest. In the case where the money is not borrowed, but raised by direct assessment, the municipality has prevented some of its citizens from profitably using the money taken from them by taxation to be invested in the lighting plant, so that even in the exceptional case the possible profit to the taxpayer on the money withdrawn from his business has to be considered. But the rate of interest on municipal bonds is usually less than the rate of profit that a private owner is willing to accept on money invested in the electric-lighting business. It is four per cent as against six or seven or eight per cent. In the final analysis, the difference between the cost of lighting by contract and that of lighting at cost by a municipally-owned plant, should not exceed four per cent on the capital invested in the plant. I assume, in making this statement, that the rate of interest on city bonds is a fair measure of the profit that investors expect on a secure investment. If the investment in the electric-lighting plant were equally secure, the rate of interest necessary would be no greater. The security depends so largely on the policy of the municipal authorities that it may approximate to that of municipal bonds on the one hand; or, on the other, it may be of the same order as the stock of a speculative gold mine or a Klondike expedition. In saying that the difference should not exceed four per cent, I am to be understood as implying such conditions as take the investment out of the speculative class. I am also to be understood as implying that proper salaries for management have already been paid out of earnings, and that the profit mentioned is that payable to capital alone; in other words, an exact parallel to the payment of interest on a municipal bond.

THE ADVANTAGE OF THE CONTRACTOR

It follows that if the organization and equipment of an existing plant engaged in the supply of electric light to private consumers is available for the purpose of performing public lighting, this maximum difference of four per cent can be thereby reduced or even reversed. In every case the difference should be reversible. There are causes to be considered later which tend to the contrary, but the fact remains that there is no irremovable cause why an existing electric-lighting plant should not be able to perform public lighting at a less price than the municipality can do the work itself.

THE DISADVANTAGE OF THE CONTRACTOR

Of the causes that tend to the contrary, one is that the plant which has a contract for public lighting may have very little private service, or none at all. Some other plant in the same city may do all or most of the private business. This condition of affairs can be only temporary. The consolidation of the two plants is an economic necessity, certain to arrive in time. The only condition justifying the existence of two plants in the same city, is that the city is so large as to make a division of territory desirable, and even in that case an operating agreement is to be preferred to complete independence.

The public has been told that consolidation of plants is not to the public interest. This is an error, and the way to prove it such is to give to the public the surplus profits of consolidation in the shape of lower rates and better service—either or both.

Another cause tending to handicap the contractor, is that few municipalities will make contract for a long term of service. Even the advocates of municipal ownership who are willing to issue twenty- or thirty-year electric light bonds, and who will not write off more than three or four per cent for depreciation of plant in making their estimates of city operation, will protest against a contract's running more than a year or two. They claim for the municipal plant all the advantage of a secure investment, and simultaneously deny these advantages to the contractor. We know that the securing of a long-term contract permits the installation of the most economically-operated machinery, and reduces the percentages of profit, which must be earned annually. The objection to the long contract, that it denies to the city any share in the profits of possible improvements effected during the term of the contract, can be met by so drawing the contract that the margin of profit shall plainly be reasonable to begin with, and that the city may share in the results of improvements in consideration of guaranteeing a similar reasonable profit on the investment to be made in such improvements. A ten- or twenty-year contract with such a clause could be safely taken at a very low price.

A possible solution of this problem is city ownership of the plant, combined with operation by a contractor. I think that this plan may by and by become common. It involves too many details to permit of my discussing it at present.

The very worst handicap that a contractor may have to carry, is excessive capitalization. Here it must be noted that many municipally-owned lighting plants do not report all their capital expenditure, so that in carelessly-made comparisons of fixed charges the contractor appears to have overstated his investment in order to increase the apparent cost of operation. Any comparison must be on an identical basis for capital as well as for operating charges. And for the purpose of adjusting prices between municipality and contractor, only one basis for capital charge is acceptable, namely, the present value of the plant; in brief, a properly-made inventory. This proposition is so radical that I state the reasons for it.

CAPITAL ACCOUNT

The possible bases for a capital charge are as follows: First—The face value of the securities issued by the plant. That this is an impossible base of adjustment is too well known to all electric-light men. Second—The current market value of these securities. This is impracticable, because many securities are not on the market, and because the immediate earning capacity of a plant affects the price of its securities, and because—last, but not least—some securities are speculative rather than industrial. Third—The actual cost of the plant. This would be proper if all plants had been built at the same time and if no plant had been obliged to be rebuilt. As it is, the construction cost of two plants built, the one in 1888 and the other in 1898, the two of identical capacity and of similar type, may be to one another as two to one; the earlier plant may have cost twice what was paid for the later, solely because of the reductions in the prices of machinery and material of construction in the last ten years.

The only remaining possible base for a capital charge is the present value of the plant; and I do not think that any other can be made acceptable for the specific purpose of adjusting a price for public lighting. It does not follow that the capital account is to be readjusted to a corresponding figure. It is only requisite that the company accept as a proper profit on public-lighting business an allowance based on inventory value of the investment. It would be well for the industry, however, if all our capitalizations were brought near to present values. And one good result of revaluation would be a logical sequence —the depreciation of the investment from year to year would necessarily be admitted as a proper charge against revenue. If a profit is only to be allowed on capital sufficient to construct a plant at the comparatively low construction prices now ruling, any further decline in cost of construction must be considered an impairment of capital, to be made good before any profit can be paid. It is not to be understood that I expect an electric-lighting company to stop dividends or to reduce capital stock in order to make good in any one year an extraordinary depreciation charge, due, for instance, to the replacement in the year of old-type machinery with new, in order to meet a public demand for a higher grade of service. Such extraordinary charges must be financed according to well-understood rules. The loss of value of the old machinery does not occur in an instant, but is a process continuing through several years. So far as it is possible, this loss of value should be anticipated by charges made in advance—in other words, by the accumulation of a renewal fund. But where this has not been done, the charges should be distributed over a proper period with due regard to all interests involved—in other words, so as to secure the greatest good for the greatest number. The principle is all-important. The detail as to how a proper depreciation charge shall be put on the books, is a matter to be disposed of in the most convenient manner.

IN CONCLUSION

Having recited my premises, I now state my proposed policy as a recommendation, as follows:

I recommend that the association declare by resolution:

1. That a municipality may properly provide for public lighting, either by the ownership and operation of an electric-lighting plant, by the operation of a contractor under lease of a municipally-owned plant, or by contract with the owner of a private plant.

2. That the supply of electric light to private users is not properly a municipal function.

3. That the performance of public lighting under contract by a private plant in connection with the supply of electric light to private users is essentially the method of least expense.

4. That the existence of two electric-lighting plants

in the same territory is an economic error, tending to increase the cost of production, and thereby the selling price; and that the maintenance of competition is to the detriment of the public.

5. That public lighting by contract should be performed at the lowest price consistent with a reasonable profit on the value of the investment; that no electric-lighting contractor should demand more than such a profit, and that each municipality should protect the contractor in the enjoyment of his profit, and against impairment of his investment, in order that a minimum profit may become reasonable.

6. That, in order to adjust prices in the absence of competition, it is necessary that costs be ascertained and prices approved by a competent authority, acceptable to the public as well as to the contractor.

7. That, in the absence of a constituted authority competent to ascertain costs and prescribe prices, members having public-lighting contracts under consideration should endeavor to have the adjustment of the contract price undertaken by a temporary commission, or arbitration committee, who will adopt as the basis of adjustment the principles set forth in these resolutions, particularly in resolution number five.

8. That there is no essential difference in the organization of municipally-owned plants requiring a different analysis of costs from that which is proper for private enterprises, and that the publication of the costs of municipal lighting plants, properly analyzed, is beneficial to the electric-lighting industry. Further, that the similar publication of the costs of private plants is desirable, but is at present impossible because of its advantages to actual or possible competitors.

In conclusion, I desire to say that the tendency of public opinion appears to be toward some interference by and on behalf of the public with corporations performing so-called public services. Such a tendency is a concomitant of our social progress. It is not merely a temporary surge, but is a part of a general movement. It cannot be withstood, but may be guided into proper channels. The general result of any such movement is for good; the damage which is done to individual rights is incidental, and is more often the result of needless opposition by the individual. In this matter of public lighting the right of the community to interfere is so evident that it has been one of the first subjects considered, and will be one of the first disposed of; and its priority in time will establish its disposition as a precedent for the future disposition of similar questions. There is immediate need for clear thinking and for well-considered speech and action—for speech telling the public that electric-light companies desire to do business according to the golden rule, and for action plainly in conformity with the speech. I believe that this association can appropriately speak for its membership, and that its members are willing to live up to the principles which the association may enunciate.

DISCUSSION

THE PRESIDENT: I will now call upon Mr. Samuel Scovil, of Cleveland, for some remarks on this subject.

Mr. Scovil read his remarks as follows:

Mr. President and Gentlemen:

Each of us, I think, will agree with the statement that Mr. Dow makes in closing his able paper, that there is immediate need for clear thinking, and for well-considered speech and action, in reference to the attitude being assumed by the public toward those corporations performing so-called public services.

Most of us will agree that the hostility in the public mind toward these corporations is, in some measure, the logical outcome of the methods that some of the companies have pursued in the past, which methods, in themselves, are most reprehensible, whether they were adopted voluntarily or involuntarily. Nothing is to be gained by denying that this has been an important factor in bringing about the conditions with which we now have to deal. While willing to admit the truth of this statement, I hold, however, that the hostility alluded to is in quite as great a degree attributable to the teachings, misrepresentations and accusations of a certain school of theorists and dreamers, whose one universal remedy for every political ill, real or imaginary, is to increase the functions of government.

Certainly this association can do its members no greater service, and, incidentally, the other corporations performing quasi-public services, than by adopting some plan of action looking toward an improvement in the relations between those companies which it directly represents and the companies which they serve. How best to accomplish this most desirable result is a problem not easy to solve.

In regard to public lighting only, Mr. Dow advocates a declaration of principles by the association, and a recommendation by it to its members of a policy based on those principles. If his suggestion be acted upon, the association must be careful that the principles that it enunciates, and the recommendations accompanying them, shall be such that, wherever they may be fully accepted and adopted, they will result in reasonable prices being offered to the municipality, and a fair return to the company upon its invested capital. I use the words "invested capital" advisedly, for I take decided exception to the principle laid down by Mr. Dow, that the *present value only* of a lighting plant is the proper basis upon which to adjust a price for public lighting. The growth of the electric-lighting industry has been almost unexampled in rapidity, and, as a natural sequence, much of the apparatus originally installed in the average lighting plant has been replaced, not once, but several times, because it had become obsolete. This was no ordinary depreciation, such as might properly have been anticipated; it was extraordinary in its character and in degree. For reasons well understood by you, it was impossible for the managers of these plants to secure for the service rendered by them a price that would allow them to cover this depreciation, even could they have anticipated it. As a case in point, I will state that I am informed that there is not in use to-day in the lighting plant owned by the city of Chicago one single piece of the electrical apparatus placed in service when the plant began operation. It was the necessity for buying new equipment, and charging its cost to operating expenses, that made the cost of operating street arc lamps by the municipal plant of Chicago only $96.40 per lamp per year for labor and material. You will find these figures given as the cost on page thirty-five of the mayor's message for 1896.

Aside from this fact, the original investors in electric-lighting apparatus had to pay for patent rights, and these constituted a by no means inconsiderable part of the aggregate amount of capital that they had to put into the business. In an article by the president of this association, on the development of the central station, he says that in the early days of the business it was necessary to do the cheapest possible engineering and construction, in order to meet the necessities of the slim exchequers of those that were *bold* enough to embark their capital in this business. There was no clamor then for the municipality to municipalize the industry.

Let us assume that a municipality had, ten to fifteen years ago, built a plant for itself. The municipality, if it kept its service up to date, would necessarily have had the same experience as did the private owner in reference to replacements. How would the cost of its plant compare with the cost of its replacement to-day? It could probably be duplicated for less than half its cost. Now, if an expert were sent to that town, to ascertain what it was costing it to do its public lighting, would he be justified in ignoring the total capital expenditure made on its plant, and in taking only one-half of such expenditure because the plant could be replaced to-day for that amount? To put the case in another way: Suppose the municipality had issued bonds for the total expenditure on its plant, and these bonds, as would probably be the case, were all now outstanding; no one would deny that the interest on such bonds would necessarily be a part of the cost of its public lighting service. This is in a measure the position in which many of the private lighting plants are to-day. Moreover, it is a fact that it has been the very readiness of the private lighting companies to replace and enlarge their original installations, and of the street-car companies to do likewise, that has made possible the great development, both as to efficiency and cost, of the electrical appliances of to-day. If the municipalities had entirely undertaken the business at the outset, it is not at all unlikely that the development and consequent extraordinary depreciation would not have been anything like as rapid.

As bearing upon this point, let me call your attention to some figures in an article in the March issue of *Lightning*, an English paper. The writer says that the extent to which street arc lighting has been taken up in England bears no reasonable proportion to the state of things that should really exist, and that does exist, in America. He then gives tables showing that in American towns in forty-five states having a gross population of 14,384,000, there were 60,397 arc lamps; whereas in thirty-one English towns, with a population of 7,497,079, there were 3,864 arcs; or, in America one lamp to every 250 people as against one lamp to every 1,940 people in England.

As I understand it, the proposition made by Mr. Dow, if accepted by this association, might well be stated in a resolution as follows:

RESOLVED, That we, the managers of private lighting companies, in convention assembled, deliberately declare that it is perfectly equitable that part of the capital that we have invested in good faith and with commendable enterprise, be now confiscated by the municipality that we have been serving.

In this connection, let me call your attention to the position taken by Professor Ely, of the University of Wisconsin, one of the foremost and ablest of the advocates of municipal ownership. He says: "The mode of accomplishment (in changing from private to municipal ownership), of course, requires careful consideration, but only a few suggestions can be thrown out at present. One of the most important is that a fair, but never excessive, value should be paid for the property acquired, and *a fair value does not mean simply the cost of duplication of a plant.*" The professor's position is simple justice; he recognizes the right of private owners to their investments.

Do not misunderstand me, gentlemen. I do not claim that a municipality should pay more for its public lighting than it would cost it to do the work itself. What I do claim is, that there is nothing in the history of municipally-conducted industries, either at home or abroad, that would indicate that they can approach the privately-conducted enterprises in economy of operation if the municipality will grant and secure to the private company the same privileges and security that it assumes for itself. As a well-known writer states it: "There is an economic advantage inherent in private ownership that cannot be acquired by a municipality. The operation of this advantage creates the profit for which the company works, and which, when created, belongs to those creating it, as justly as the pay for a day's work belongs to the honest workman. This economic advantage ceases to exist when an industry passes from private to municipal ownership. It eludes municipal ownership as surely as the secret of life evades the surgeon's knife. It cannot exist in slavery; it is the offspring of freedom. It is the advantage of personal responsibility, of guaranteeing the saving to the one who saves, the economic advantage of a hope. This advantage stimulates enterprise, induces thoughtful care and inspires energy."

The margin of difference between the two systems will, in my judgment, allow the private companies a reasonable return on the capital they have invested in their plants. To take the present value of these plants, and oblige the private companies to furnish service on such a cost, is to assume that the municipality has a right to wipe out capital that it invited into its service, and then to take unto itself, in addition, all the economies that result from an intelligent self-interest.

There is one other principle that Mr. Dow asks us to accept, to which I think exception should also be taken. He says: "The only sufficient reason why a municipality should contract with a private company for public lighting is that the private company can do the work, and is willing to do it, cheaper than the municipality can itself do it by direct operation of a public lighting plant."

In my opinion, preference should, in every case, be given to the private company at the same cost.

A contract made with a private company is a known expense; municipal ownership and operation is an unknown expense. Aside from this fact, however, there is a large and an *all-sufficient* reason why private enterprise should be given the preference and individual effort be thereby stimulated. The question as to whether the municipalities of this country shall own and operate their own lighting plants, may seem to be a small matter except to those whose money is invested in such plants. The axiom, that it is the first steps that count, is as true of a community as it is of an individual. Once fairly started upon the policy of the municipalization of all public utilities, who can tell where governmental interference with individual effort will stop? Will it stop with the municipalities? No! Led by the theorists, dreamers and politicians, the unthinking masses will cry "More! more!" and the inevitable result will be the institution, finally, in our civic, state and national governments of a crushing, bureaucratic system, which will seek to regulate almost every activity of the individual from the cradle to the grave; the substitution for the free government of a democracy, of the paternalism of a despot. If the American people apprehended clearly the degradation into which they would be plunged by the realization of the theories of the dreamers who can think, as one writer puts it, of the state only as being a beneficent power, exhaustless in resources,—that, like a fairy, will turn their feet from every pitfall, and by the wave of a wand shower upon them all the blessings of existence,—they would trample upon them as would the individual upon the poisonous adder that seeks to injure him. All history and experience show that wherever a people has entrusted its liberties to its representatives, to be exercised through a centralized power, those liberties have been lost to it. Instead, therefore, of taking any steps in the direction of the restraint of individual effort and private initiative, let us hold fast to the fundamental principle enunciated by the fathers of this republic, that the only government of a free democracy is limited to the preservation of order and the enforcement of justice.

The following would seem to be much more acceptable than Mr. Dow's proposition, and would be more in accord with the spirit of American institutions, which is, to interfere as little as possible with the individual activities of the citizen:

The best interests of the public welfare require that a municipality should contract with a private company for its public lighting, if the private company can do the work, and is willing to do it, at a cost not greater than if supplied by a plant owned and operated by the municipality itself.

THE PRESIDENT: I have great pleasure in calling upon Mr. H. M. Atkinson, of Georgia, to address you on the same subject. This is Mr. Atkinson's first appearance at one of these conventions, and I am sure we thank him for coming so far to address us on this important matter.

MR. ATKINSON: The remarks I am about to make, scarcely deserve the introduction made to them by your president. I only decided within the past forty-eight hours to come to the convention. The suggestions I shall read were thought of on the train, and written after I reached here last night. I can only hope that they may be of some use to the association. I suppose I was picked out to address the meeting on this question, mainly, because I have been one of the victims of this agitation during the past seven years. I regret that an entire lack of previous knowledge of the scope of the remarks of Mr. Dow and Mr. Scovil has rendered it impossible for me to answer them, or for my remarks to have any direct bearing upon what they have said. I tried to get out of preparing the paper, but your president insisted.

Mr. Atkinson then read his paper, which follows:

Mr. President and Members of the Association:

Nothing but my deep interest in the question of public lighting with relation to public ownership or control would tempt me to address such a meeting without preparation. When your president, early in May, honored me with an invitation to take part in this discussion, I wished to accept, but my engagements and movements were too uncertain, and I had to decline; but, having decided during the past forty-eight hours to come here, enforced idleness on the train, and my zeal, are my excuse for the following, I am afraid too random, remarks; and then, too, I do not think any central-station man can afford to neglect a call on this subject. I propose to get through with it as soon as I can, and get to the, to me, more enjoyable part of the programme.

I take it that it is not the purpose to discuss here specific cases or grievances. Such an association as this should adopt a platform enunciating its principles on this question, which, by its conservatism, temperate tone, fairness and broadness, will appeal to the taxpayer and intelligent voter. This platform should be carefully prepared, should avoid anything aggressive in its tone or calculated to excite the opposition of advocates of the policy. We should state that we are opposed on principle to municipal ownership, not alone as owners of electric-lighting companies, but as taxpayers ourselves. We should state that we are not engaged in a partisan fight, in assuming that whenever one of our members is attacked, he is of necessity in the right, and must be protected; but that circumstances will solely govern the position we take in each case. We should state that after long experience and earnest study, we, as honest business men, believe that private corporate service under proper legislative control is far better than municipal ownership. We must distinctly state that we will not uphold our members unless they are honestly endeavoring to give the best service at the very lowest living prices, taking into consideration local conditions. We must show that private ownership under proper control, means all the advantages of public ownership without any of the risks. We should emphasize the conditions of legislative protection as they exist in England, France, and in Massachusetts in this country. We should dwell on the depreciation losses to which we have been subjected during the past ten years, and which are still pressing upon us. We should counteract the prevailing idea of great profit in the business. We should condemn, at the start, high prices, and the policy of those who exact them; putting ourselves on record as believing that, as street-lighting contracts cover long hours and much consumption, they should be treated accordingly.

We should adopt a standard system of accounts for ourselves, and advocate the adoption of such a system by every municipality, one that will appeal to all business men. We should endeavor to show that cities adopting this policy are providing the soil upon which rings and corruption cannot exist. We should counsel fair and accurate expressions of facts and figures on both sides, emphasizing the injustice done by careless, inaccurate, unstudied statements. We should urge more complete and adequate methods of bookkeeping in all municipalities. We should drive home into the minds of the people the fact that a city's only source of income is through taxation, or by bond issues, which mean taxation perpetuated; that every dollar raised by the former method is costing them interest, as much as the latter. We must urge that cities count cost as fully as private persons. Our fight, in short, is the fight of good and honest government. We must stand fairly on the platform that we, as taxpayers as well as owners of electric-light works, are opposed to the policy of municipal ownership and operation, as our experience has shown us what it is. We must show how legislative control, requirements and penalties create a degree of responsibility never existing as regards a municipal corporation; how elimination of the factor of self-interest is an effective barrier to economy in production or operation, and always will be; that private enterprise will always outstrip municipal ownership, in filling the gap between supply and demand; that cost under contract is limited to price, and under municipal ownership cost is unlimited. We should point out the difficulty of ever getting true statements of cost if this policy is inaugurated, as advocates of it will not willingly issue statements condemnatory of themselves, and politicians will not take action that will decrease their patronage. It should be pointed out to taxpayers and voters that municipal ownership of electric-light plants will only be a stepping-stone to ownership of numerous other industries; for if ownership of one is advisable, why not of all? We should call attention to the enormous patronage to follow, and should urge that it means absolute control of our municipal affairs. We must urge that no class is exempt from love of power, and none so pure as to fail to abuse it. We must ask taxpayers and voters if our cities are now so well governed, and our taxes so low, as to make it desirable to adopt this policy, which means continuing bond issues, or increased taxes. We should also ask them if municipal corporations have not enough to do now in maintaining order, protecting the weak against the strong, adopting certain measures for the benefit of the health of the people. Are they doing these things so well now that we had better intrust to them more difficult problems? We should call upon them to bear in mind that public officials in cities, and elsewhere, are elected with reference to their popularity, their ability to organize, and sometimes with reference to the amount of money they are willing to spend on an election. They are nearly always chosen from among persons known as politicians, who have not been trained, as a rule, for the ordinary business walks of life, much less in a technical way.

We should educate public opinion to the unfairness of municipal competition with capital invited and encouraged to occupy the field while an industry is an experiment, so long as such capital furnishes good service at a fair price, and that such competition is equivalent to condemnation and confiscation of property without compensation. Some may say that this is a big problem. How is it to be done? By organized work. We can make no better investment. We should have an organized department to collect data, systematically and accurately, and furnish it to members on call. This department must be continuing and permanent. A careful examination of municipal-plant costs should be made. Newspapers, magazines, etc., should be carefully clipped of all items bearing on the question. Bulletins or circular letters containing these clippings should be sent the members or information where to get them, which would do just as well. Special aid should be given threatened companies, provided their fight is just, by suggestions and preparation of articles for publication locally. All this will cost money, but it will pay, and will not cost as much as fighting alone, as we do now. The tone of all this work will have to be carefully regulated; give it a too partisan aspect and it will be without effect.

There is no doubt but that much of the municipal ownership is natural. One or all of three conditions usually precede it:

1st. Extortionate rates, maintained, perhaps, by combination.

2d. Poor service.

3d. No service at all, because the field offers no inducements to attract capital.

There is a fourth reason for it—the political—but it should be handled separately.

This association should have nothing to do with fights that its members have brought on themselves by unreasonably high prices or defective service, except, after careful investigation, to condemn their policy. The worst enemy of the electric-lighting interests is the company that exacts unreasonably high prices, whether for good or bad service. This course is largely responsible for the whole agitation. One instance of this kind of policy that results in municipal ownership does enduring harm, as it furnishes material for endless misstatements and mistaken opinions.

The agitation of the policy for political purposes is getting to be more common. It is the old story of corporate interests against the masses. The only remedy for this is the education of the voter and the taxpayer on the lines already indicated, so that honest, capable men will be elected to office. This can only be done by properly collected and tabulated data, for use in each place where the trouble exists. The political attack is the most aggravating of all. Many a well-managed company, doing its duty honestly, giving good service at reasonable and constantly-reduced prices, is attacked by politicians seeking office, for no other purpose than to attract the vote of the masses, and without any regard for consequences or for the injury done vested interests. There is no way to cure this trouble directly, and the only way to reach it is through the voters themselves. Arguments, facts and statistics are not for politicians of this character. This is the hardest kind of fight to meet. This association, by an organized effort, can be of great service to its members; and the work done as an organization, with co-operation on the part of the members, will be more thorough than separate work. Collecting ammunition, and writing newspaper articles, is the nightmare of all central-station managers.

In conclusion, let me say that this question is important, not alone from our selfish interests, but on account of the interests of taxpayers everywhere. I am firm in the belief that municipal governments were never intended to undertake the operation of business enterprises, such as electric lighting, and other public services of a kindred nature. If we intelligently and persistently try to educate the intelligent voter and taxpayer, we are bound to build up an opposition to this policy that will end it.

One last word. Let us be good-natured and temperate in all this work. Denunciation is no argument, and does no good; though I confess it is easier to give this advice than to follow it, but it is the best policy.

I beg to thank you for your attention.

THE PRESIDENT: Mr. Ernest H. Davis, of Williamsport, Pennsylvania, will address you further on the question before the meeting.

MR. DAVIS: Mr. President and gentlemen: As a member of this association, what I desire to get from it is protection to the utmost extent possible. The conclusion I have arrived at individually is that investments in electric-lighting plants will earn more, be better secured and more stable, if such interests are protected by a properly-regulated state commission rather than by the efforts of individual companies or by the use of any statistics. Therefore, so far as the position of the association is concerned, if it desires to take any action, I would suggest that action be taken to get the forms of commissions existing in other countries, and the facts and results of these commissions as regards existing companies.

On the other hand, as we are now,—every company protecting itself the best way it can—each company must necessarily rely upon existing information to combat the idea of municipal ownership. The foundation of the movement is a belief that a municipality can furnish better service at a cheaper rate than a private company. That is the question we met in our city, and it is practically the question raised, and which must be met, everywhere. I was driven to the necessity, in my individual case, of spending a large sum of money in a personal investigation of a number of well-known municipal plants in the United States. I examined a few, and the result of the information was that a committee of councilmen, who happened to be business men, made an investigation of these records, and reported in our favor. The result in our city was that the movement was defeated, and we still retain our contract.

My idea is that the proper way to deal with this question is to get official information. We can do that only by sending a competent man to the plants in question, and getting the fullest information possible, not only from the employees of the plant, but especially from the records kept. It is not always possible to do that, as I know. Find out how much it costs the municipalities to supply light, and give that information to such members of the association as have contests on hand, and let them use it in the best way.

THE PRESIDENT: Gentlemen, this subject is one of great interest, and one about which we could talk for a long time; but we have a considerable amount of business that we ought to transact to-day in executive session, and I would, with your permission, ask that some one move that we go into executive session, and take up the consideration of various matters necessary in connection with the welfare of the association.

MR. AYER: Mr. President, I move that the convention go into executive session.

The motion was carried, and the meeting adjourned to executive session.

ORDER OF BUSINESS

WEDNESDAY, June 8th, 1898.

THIRD SESSION, 10.20 A. M.

1. Paper—"General Distribution from Central Stations by Alternating Currents." By HERBERT A. WAGNER
2. Paper—"General Distribution from Central Stations by Direct Currents." By LOUIS A. FERGUSON

FOURTH SESSION, 3.15 P. M.

1. Discussion of Mr. Wagner's and Mr. Ferguson's papers. (Continued.)
2. Announcements

THIRD SESSION

The meeting was called to order by the President at twenty minutes past ten.

THE PRESIDENT: The subjects to be considered at this morning's session are "General Distribution from Central Stations by Alternating Currents," by Herbert A. Wagner, St. Louis, and "General Distribution from Central Stations by Direct Currents," by Louis A. Ferguson, of Chicago. The intention is that these two papers shall be read, and that members shall then be given an opportunity to enter into a general discussion upon the relative merits of the two rival methods of distribution. I have pleasure in calling upon Mr. Wagner.

Mr. Wagner read the following paper:

GENERAL DISTRIBUTION FROM CENTRAL STATIONS BY ALTERNATING CURRENTS

BY HERBERT A. WAGNER.

Ever since the installation of the first few pioneer alternating-current central stations, just ten years ago, we have heard it predicted with persistent reiteration that for the distribution of current for lighting from central stations direct current was a thing of the past, and that in a few years the alternating-current transformer system would hold the field without a competitor.

To many, this prediction may seem to have been fulfilled, considering the enormous number of alternating-current plants, compared with direct-current, that have been installed, and the remarkable impetus given to electrical industries by the development of alternating currents.

The great success achieved in the transmission of power by polyphase alternating currents in the last three years, has but strengthened this general belief, and left fewer champions to adhere to the direct-current cause.

These great achievements, I say, have led the enthusiast to think all progress confined to alternating systems of distribution. Deeper investigation, however, shows that while in point of number the alternating-current stations, reaching into the thousands, completely overshadow those of direct-current, there are few really large stations, outside of water-power plants, that are to-day employing alternating currents for distribution, and that while enormous investments have been made in direct-current stations in our larger cities, comparatively small amounts have been invested in alternating-current work.

The alternating system was heralded as providing a means of distribution with a great reduction in first cost of plant, and for years the development of the system has been made with this the principal end in view. On the other hand, direct-current distribution in the form of the Edison three-wire system has been steadily and intelligently developed to the highest standard of economy of operation, simplicity and permanence. In the same city, alternating-current stations have not, as a rule, been successful in competition with three-wire stations; their service has not been as good, and their profits have been smaller.

I may startle many by stating frankly the discouraging fact, which has been barely whispered at times, that, judged by the standards of the magnificent Edison properties in many of our larger cities, few alternating-current central stations in the United States have been a success. Do not imagine that this damaging admission, however, is an indication of any loss of faith on the part of one who has been identified with alternating-current work since its début, as it were. Far from it. The fault lies, not with the alternating current itself, but with its application. Its few apparently inherent deficiencies, such as the difficulties of operating motors and arc lamps, have been shown to have been only awaiting discovery and development, and were at our disposal almost as soon as these important divisions of central-station service were operated with success from the Edison three-wire system. These can, therefore, hardly be held responsible for the difference in the commercial results obtained with the two systems.

As I have said, the ends in view in the development of the two systems have been radically different. The one was to produce a given amount of light for the minimum of investment; the other was to provide a permanent investment that would render the maximum of profit. These standpoints in general mark the difference between the manufacturer and the user, and we find these two systems developed in this way,—one almost entirely by the manufacturer, and the other by the combined efforts of the various users. The results are the natural effects of progression along these lines.

Few opportunities have we had of comparing the two systems from the same standpoint and under like conditions. The purpose of this paper is to show the alternating current applied from the same standpoint, compelled to fulfill the same conditions, and then to compare the results with the best produced with direct current.

To better contrast the different methods of distribution, we will review briefly those in general use before describing the most recent developments.

The early alternating-current stations were installed on the principle that the drop in lines with distribution at 1,000 volts was so small that it was practically negligible. Two wires were accordingly run out from the station, passing along those streets where light was to be furnished, and lights were connected *ad libitum* at any desired points between the station and the farthest end, without reference to such trifling considerations as difference in potential. Distribution was attempted in this way for years, and in many places is still in operation. Lines are even being constructed to-day without any notion of a system of feeders and mains, although an almost perfect system for the maintenance of uniform pressure was in operation in many Edison stations before the first alternating station was in existence. Fortunately for the operators of such models of simplicity, the current delivered has usually been so small in quantity that with the proverbial No. 6 wire, which seemed to possess virtues not affected by distances, the difference of pressure between neighboring customers rarely exceeded ten per cent.

A few more enlightened experts—plants were always installed by experts in the early days—eventually conceived the novel idea that if the drop, a little of which they had discovered by that time, could be confined to a greater extent to those portions of the lines where there were no lights, some might be spared from the lighting districts. A few feeder lines were therefore stuck in here and there to boost up the pressure where it was lowest.

The regulation was all effected by means of the dynamo field rheostat, and the pressure indicated by a voltmeter on the secondary of a transformer whose primary was connected to the 'bus bars on the switchboard. A few lamps were also often operated by the same transformer to light the switchboard or other parts of the station. The station attendant was, of course, in absolute ignorance of the pressure at any point on the lines where lamps were used. The pressure was therefore usually run high enough to be on the safe side. The attendant was sometimes instructed to let his voltmeter needle follow gently the manœuvres of his ammeter, as there was thought to be a more or less intimate connection between volts and amperes and the volts ought not to be allowed to get too far behind.

If any one ever breathed a suggestion of pressure wires, it was probably his last breath. At any rate, he was never heard of again. What! pressure wires with alternating current? Preposterous idea. Alternating and progression were considered almost synonymous terms. Antiquated ideas must be abandoned.

This faintly-whispered need might, however, be heard again, so, to meet the emergency, a compensating voltmeter was produced that could be adjusted for any drop in the lines. It was ingeniously arranged so that a small series transformer in the main line would send currents opposing those operating the voltmeter, thereby making the needle or index drop back approximately proportionately to the current in the line. This device was a great help, and caused the drop in lines to jump into prominence at once. It would be quite perfect if the drop in alternating-current lines were proportional to the current, but it is not. The power factor of ordinary alternating-current systems is usually quite low at light loads, and, except with very small wire, an ampere may therefore produce much more drop proportionately at light load than at heavy load.

One alternating-current station of which I have intimate knowledge, has used pressure wires in connection with each feeder for years. There may be a few others, but they are rare exceptions even to-day.

The usual system of distribution provides a separate transformer for each customer. In many cases, this implies the use of a very small transformer. It is impossible to make the efficiency of small transformers high. As each customer may at times use all of his lamps, he must have full transformer capacity for such an emergency. The ordinary ratio between maximum station loads and the number of lamps connected, is in most cases under fifty per cent where meters are employed. The transformers then being of a total capacity equal to the number of lamps connected, average at best only fifty per cent of their rated capacity at the maximum station load. In most stations the average load generated is much less than twenty-five per cent of the maximum load, and, therefore, with twice the transformer capacity of that represented by maximum station load, the average transformer load would not exceed ten per cent of the transformer capacity, all the year round.

The efficiency of the average modern transformer of usual size at ten per cent of its rated load is not over sixty-five per cent, and the average of transformers at present in use not more than fifty per cent. It is perfectly safe to say that there is not an alternating-current station to-day using individual transformers for each or neighboring customers that can show an average efficiency of distribution of over sixty per cent, and few that can show over fifty per cent.

In Europe, it is, to some extent, the practice to use transformer sub-stations with low-potential distribution from these points. Transformers are cut in and out at these sub-stations by attendants according to the demand for current. It is doubtful if, after paying interest on the investment in property and housing for these transformer stations, together with the investment in instruments and switches required, and the attendants' wages, there is very much saving effected. Had we nothing better to turn to than these systems, the cost of distribution from large stations would be extreme compared with the direct-current, Edison three-wire system, and competition with the latter could not be a success.

Another very important consideration is the economy or efficiency of lamps used. To employ successfully the highest-economy lamp made, a very uniform pressure must be maintained. With the usual alternating-current system, and with an equally good disposition of feeders and mains, the variations of pressure will exceed those in a direct-current system by nearly three per cent, on account of the transformer drop, and to secure even this limit of variation, pressure wires must be used with each feeder.

It is not surprising to find, therefore, that almost all alternating-current stations are using lamps requiring twenty per cent more current than those used by direct-current stations.

I cannot refrain from remarking here that to operate any station, alternating or direct-current, without pressure wires, is to be worse than penny-wise and pound-foolish. In any alternating-current station employing overhead wires, the saving in lamp renewals would equal the cost of pressure wires in little over a month's time. I might also add that the total loss of lamps is not the most serious result of variations in pressure. Such variations cause a rapid decline in candle power, and low candle power means disaffection of customers and the increased use of gas.

Now, let us leave for the time the alternating-current station and its usual system of distribution, and adjourn to a modern Edison station, to see if there can really be anything learned from so antiquated a source. On entering, we see at first large direct-connected generators running in multiple. We have also seen those in a few alternating-current stations, and perhaps of larger size. We next see a very compact and convenient switchboard. Neither is that altogether new. But let us ask to see the system of distribution; for that is what we most want to look into.

On the plans of this system of distribution a remarkable network of feeders and mains is laid before us, most carefully calculated for the maintenance of uniform pressure. Means for regulating more or less independently the pressure on each feeder are provided. From numerous points in the system, corresponding to the feeder terminals, pressure wires are brought to the station, and indicators show the pressure at all these points. Numerous devices and appliances are shown us which must have been the result of years of experience in the development of distribution methods. We look with admiration, and ask why, with this apparently far more perfect system in existence, have we been working so long to try to perfect a new system that cannot to-day, we are informed, produce such results. Why, indeed!

But let us look a little further. What are those massive beams? They do not seem to support anything. "Those are not beams. They are copper wires to carry the current out," we are told. "Wires? Why, they weigh tons!" "So they do, but they are necessary with this system." A very serious drawback, it would seem. Another question troubles us. Why do you occupy ground in a part of the city where property must be very valuable? Why do you not go off to one side where land is cheap? "Oh, we are forced to be near our centre of business. If we were twice as far away we should have to use four times the amount of copper in those bars." This, indeed, seems a very great defect. But are there no other defects in your system? In answer, we are told that there are no others that are considered serious.

If this necessity for using such an enormous amount of copper is the weak point of a beautifully developed system, why do we not endeavor to overcome that particular point and adopt the rest, instead of starting out anew and alone to develop another system from beginning to end? This is the question that should have been considered years ago. Why did we not start where others left off, engraft our alternating current and draw energy and strength from the old roots, instead of trying to grow from the seed to find ourselves running to limbs and branches with very little trunk to speak of. We have tried to overreach our older brother, and now lack his sturdiness and stability.

It is not too late, however, to begin afresh. We are satisfied that at the present time the Edison three-wire system of distribution is the most efficient in use and the most nearly perfect in details. We know that the usual system employed with alternating current is not efficient, and does not admit of as close regulation, but it is vastly cheaper to install.

Comparing the cost of individual transformers and high-potential distributing mains with the three-wire system of mains at low potential, we do not find a great difference in first cost in favor of the alternating. We do find, however, that the Edison feeders for the same distance cost about thirty-one times as much as for alternating current at 1,100 volts, 125 times as much at 2,200 volts, or 500 times as much at 4,400 volts. It would then appear that if we could apply alternating current to the feeders at high potential and transform down for the mains, we might reach the lower first cost of the ordinary alternating-current system and possibly retain all the best features of the direct current. To accomplish the former, the transformers must be provided at a small proportion of the cost of the alternating-current feeder, and to do the latter, they must not increase the average losses in the system. It is obvious that we could with alternating current move our station to any reasonable distance from our centre of distribution, and at comparatively small additional cost for feeders. The whole problem then seems to come down to transformer efficiency and means of regulation.

To consider the matter of regulation first. We see at a glance that we cannot use the direct-current method of regulation by supplementary 'bus bars, but we can use the booster method, and can, moreover, apply a static booster to each feeder to regulate within any desired limits and with as small gradations as necessary. In fact, the booster method of regulation was first applied to alternating-current distribution, and operates with much less average consumption of energy than either the supplementary 'bus or direct-current booster method. In this important consideration, we can therefore improve on and simplify direct-current methods.

The means of regulation having been in this way provided for the feeders, it remains to be considered what we shall do to eliminate the effects of transformer drop. As we have determined on a secondary low-potential, three-wire distributing system of mains, we can altogether dispense with high-potential mains and limit the high potential to the feeders. If we do this, we can conveniently have the transformers of the same unit capacity as the feeders, and arrange each with its primary connected to its independent feeder and its secondary feeding into the three-wire mains. We know that the effects of our feeder drop are eliminated if we regulate by pressure wires from the feeder ends. In the same way the effect of our transformer drop may be eliminated by bringing pressure wires from the secondary terminals. The feeder drop and transformer drop therefore become one, and are cared for in the same way. We can even secure better general regulation than with the direct-current system, as we have a better form of feeder regulator and have eliminated the effects of transformer drop.

Now, to return to the transformer itself and its efficiency. It is evident that, with this system, the transformer capacity need be no greater than that required for maximum station load, instead of more than twice that amount or nearly equal to that required for the total number of lamps connected. This at once doubles the average load on our transformers, and raises the average efficiency. It also incidentally reduces the first cost of transformers in still greater proportion. We also know, however, that transformer efficiency at light loads is dependent on the iron loss, and that this is interdependent with the regulation or drop. If we can increase the drop, we can decrease the iron loss, and thereby greatly increase the average efficiency. Having provided against any interference with the regulation of the system by the transformer drop, we can afford to increase that to the heating limit of the copper. In this way, a 100-kilowatt transformer can be built with an average efficiency of over ninety-eight per cent. The entire transformer loss can, moreover, be more than made up by the less loss in feeders, which we would naturally have with alternating current.

We have thus eliminated the two features in which the ordinary alternating-current system of distribution has been inferior to the direct-current, and have provided means for obtaining better regulation and higher efficiency at a very much less cost of installation than with the direct-current system.

This system was conceived several years ago, and it has since been my good fortune to have an opportunity to install a system of this kind on a large scale, which is now in very satisfactory operation. It is laid out exactly as a three-wire Edison system would be, except that there are no sub-feeders. A network of mains is planned as if for use with direct current. The feeders are all designed for 110-kilowatt maximum load at 1,100 volts, and at each feeder end is placed a 110-kilowatt transformer feeding into the three-wire network in the same manner and at the same points as with the direct-current system. The transformers are located in manholes of suitable design. From the secondary terminals of each transformer, pressure wires are run back to the station. Each feeder has an independent regulator by which the pressure can be raised or lowered. There are no primary mains, nor any connection whatever between the primary feeders. The regulators perform two functions They are used to maintain the proper pressure as indicated by the voltmeters and also to divide the load between transformers in any way desired as indicated by the feeder ammeters. It is possible to shift the entire load from one transformer and feeder to an adjacent transformer in this way without sensibly affecting the pressure on the system, and an equal division of load between transformers can be readily maintained at all times if desired. This is a very important consideration when very heavy loads or overloads are to be carried. The distribution of load on any large system is constantly changing as new customers are connected, and in large Edison stations certain feeders often become so overloaded that it is found necessary for their safety to put resistance in series with them to force some of the current to other feeders. The possibility of overloading any individual feeder beyond its share is absolutely provided against in the system described.

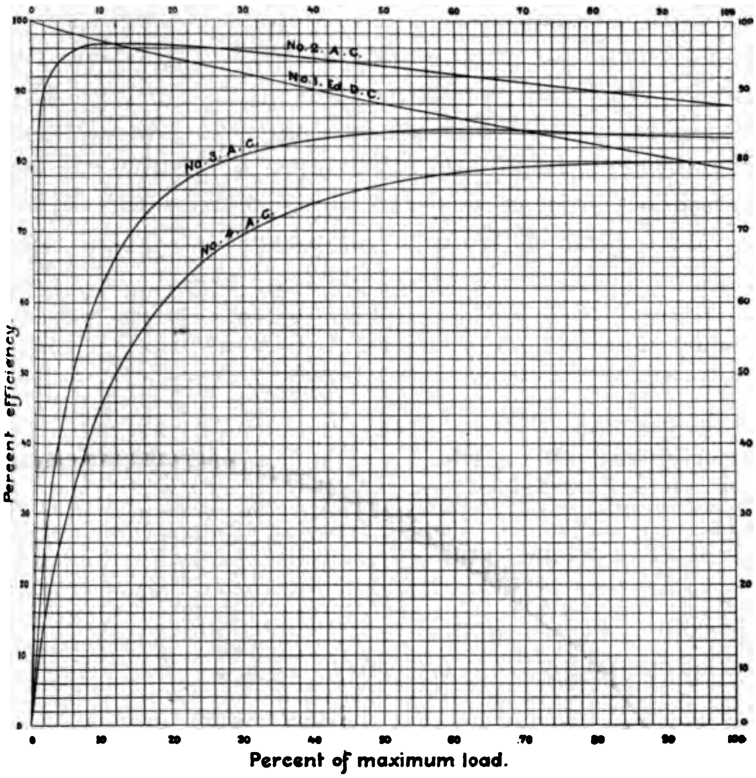


FIG. 1. CURVES OF DISTRIBUTION EFFICIENCY.

To make the arrangement of this system perfectly clear it is illustrated diagrammatically in Figure 2.

In Figure 1 are shown four curves of station distribution efficiency. No. 1 is that of a representative Edison three-wire, direct-current station. No. 2 is the new alternating-current system described. No. 3 is the usual alternating-current system employing separate transformers for each customer or for adjacent customers, the best modern transformers being used. No. 4 shows the same system, but with the average transformers found on the lines of most existing stations. These curves were plotted from the following data obtained from actual practice

	No. 1. Per cent.	No. 2. Per cent.	No. 3. Per cent.	No. 4. Per cent.
Feeder loss...........	24	8	10	10
Main loss.............	2	2	2	2
House wiring loss.....	1	1	1	1
Transformer loss, iron...	..	.23	6	12
" " copper	..	2.7	1	.5
Total loss at maximum station load.........	27	13.93	20	25.5
Efficiency at maximum station load..........	78.7	87.9	83.3	79.6

The efficiencies of distribution at assumed average loads are shown to be as follows:

Per cent.	No. 1. Per cent.	No. 2. Per cent.	No. 3. Per cent.	No. 4. Per cent.
Load, 25................	94.1	95.8	78.4	66.6
Load, 20................	94.8	96.2	75.3	61.4
Load, 15................	96.1	96.5	70.3	54.3
Load, 10................	97.3	96.4	61.9	45.1

At maximum load it will be noticed that the efficiency of alternating current No. 2 is ten per cent higher than No. 1, the direct current. This means that the same energy can be delivered with ten per cent less capacity in generators, engines and boilers, or a difference of ten per cent in the first cost of generating plant. It is pertinent to remark here that alternating-current generators also have a much

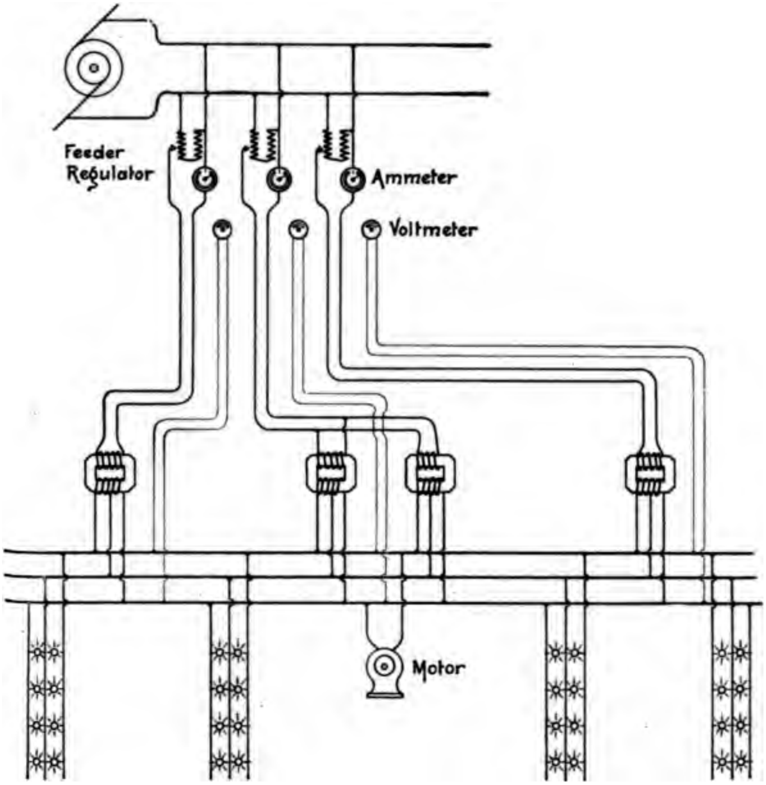


FIG. 2.- SINGIE PHASE A.C. SYSTEM
with-High pressure Feeders and low pressure distribution-
Independent Feeder for each Transformer or Group.

greater margin for overload for short periods than direct-current generators. The efficiency at average load, or the all-day efficiency of the No. 2 alternating-current system, is also shown to be appreciably higher than the direct-current. In large central stations the average load is generally found in practice to vary from about fifteen to twenty per cent of the maximum, and it will be noted that from twelve per cent average load up, No. 2 curve for the special system of alternating-current distribution shows a higher efficiency than the direct-current.

It may be asked what effect the aging or fatigue of the transformer iron will have on these figures. I answer, none appreciable. Transformer manufacturers are willing to guarantee as low as one per cent increase per year in iron loss. This means one per cent of the actual amount of energy lost in the iron, so that, if this increase continued at the same rate, it would take one hundred years to double the iron loss. Experiments tend to show, however, that this effect rapidly approaches a maximum, and that, therefore, the increase goes on at a constantly decreasing rate. The entire effect may be eliminated, if desired, about once in five years by reannealing the transformer iron at a very small expense.

It has been the practice in some European stations to cut out transformers during periods of light load, but it will be seen that cutting out transformers in the system described would only decrease the efficiency; in fact, the efficiency is higher at about the average load, and the system was designed throughout to accomplish this result.

The less we say about curves Nos. 3 and 4 the better, as at small loads the efficiency is shown to be appallingly low.

EXTENSIONS OF DIRECT-CURRENT SYSTEM BY ALTERNATING CURRENT

Several large three-wire, direct-current Edison stations are beginning to employ alternating current to extend their lighting territory beyond that possible or profitable with low-tension current. This is a recognition of alternating current which would not have been considered for a moment a few years ago. They now propose to use alternating current to transmit their energy at high potential to a distant substation, where it will be transformed to a lower pressure and then again transformed by means of rotary transformers to direct current, which is in turn distributed over the three-wire Edison system as if generated in the ordinary way. This is a very beautiful and instructive application of alternating currents, and ingeniously designed machinery. It gives the manufacturers a chance to sell additional machinery, swells the company's real estate investment and gives work to the unemployed to operate the sub-stations.

The loss in the conversion to alternating current and back is about fifteen per cent in addition to the loss in static transformers and lines. This distribution might be accomplished without the additional machinery, wire, real estate, labor, and loss in efficiency. It is hardly to be expected, however, that those who have grown up under the protection or influence of direct current would use alternating current any further than absolutely necessary until they have grown more accustomed to the new mode of travel. After looking across the stream to coveted territory for many years, they are willing to use the new bridge and to ride across at about the highest speed provided, but when they get on the other side they are more than satisfied to foot it again the rest of the way.

A much higher efficiency of distribution, and better regulation, could be secured by using the alternating-current system as it is, without transformation to direct-current, and everything could be controlled from the main station without employing labor or apparatus at sub-stations. Why do they not use it so? They say that many things cannot be accomplished as well with alternating current. If that is a challenge, we will accept it and try conclusions with them. Let us then anticipate these various objections and see what they amount to.

FIRST, EFFICIENCY

We have already seen how a properly designed system of distribution for alternating currents may be made to exceed the direct-current system in efficiency, taking the latter under its most favorable conditions. If we then add to the usual losses in the direct-current system the losses in double rotary transformation and in static transformers, the very great difference in favor of the alternating current is still more marked.

REGULATION

It has been shown how very simple and reliable regulators can be provided for each alternating-current feeder, which will secure the closest possible regulation over any range desired, and this can be effected at a loss of less than one per cent. Such close regulation can only be secured with direct current by the use of a number of generators connected to auxiliary 'bus bars, or by connecting the feeder ends to adjustable resistance connected between the 'busses of two or more generators. The first cannot be realized in a rotary-transformer station, and the last is quite wasteful of energy. Regulators placed on the alternating-current feeders of the rotary transformers control alike the pressure on each rotary, and all the direct-current feeders supplied by the same, in exactly the same way as field regulation does on a direct-current generator. Such regulation can only be effectual with a number of small rotaries not operated in multiple. The best regulation can, therefore, undoubtedly be secured with the alternating-current system.

OPERATION OF ARC LAMPS

It seems now to be the universal opinion among Edison station men that the enclosed-arc, long-burning lamp is destined to replace all the old forms of arc lamp. We will, therefore, consider this type of lamp only. Fully as well-burning lamps of this type are now made for alternating current. They are also about as free from noise as the direct-current lamps. Many will say, however, that it is impossible to get as much light from the alternating current as from direct current. That is true if we state that the same energy in the arc produces less light with alternating current than with direct current. It has been determined that the alternating-current arc produces about seventy per cent of the light to be obtained from the same number of watts in the direct-current arc. The usual direct-current enclosed arc requires five amperes at 115 volts, or 575 watts. How much of this is used in the arc? Somewhat less than eighty volts, or under 400 watts; the balance of over 175 watts being wasted in resistance.

With alternating current, seventy per cent of the amount of light would be obtained with this 400 watts, or about 570 watts would be required to produce the same light. The alternating-current arc is best operated at about seventy volts, but inductive resistance is used to bring the pressure down to this amount. This inductive resistance consumes about ten watts' actual energy, making in all 580 watts, against 575 for the direct current for the same amount of light. This difference of five watts, or less than one per cent, is insignificant.

The standard alternating-current enclosed arc consumes about 420 watts at the lamp terminals, but I have had made to order a large number of 550-watt lamps, which have replaced many series ten-ampere direct-current lamps. There are certain kinds of arc lighting to which the alternating current is particularly well adapted, of which I will speak later on.

MOTORS

The greatest argument used against alternating current used to be that it would not run a motor. It has long ago proved that it can, and that without a commutator. This subject now brings us to multiphase systems. There are two of these systems in general use, the two-phase and the three-phase. Other systems are but modifications of these and will be mentioned as such. Motors can be operated with equal facility and efficiency on either system and have many distinct advantages over direct-current motors.

For long-distance power transmission the three-phase system shows an economy in copper; but for lighting, or for lighting and power combined, it is not at all well suited. I might say that where lighting is a distinct feature, and first-class service is to be rendered from a large station, the three-phase system cannot be used successfully. On even the best generators, the windings are so entirely interdependent that a change of load on one phase will affect the pressure on the other two; but a defect even worse is the impossibility of regulating the phases independently for drop in the feeders if the load happens to vary differently on any two. Any regulator placed in circuit with one phase will effect about the same change of pressure in the adjacent phase within the usual limits of regulation. Regulation is then a question of the best possible averages, and at best is but guesswork. With the feeder and transformer drops found economical in practice, it would be practically impossible to keep the pressure sufficiently constant for high-efficiency lamps. The complication of wiring is also very serious, especially if the Edison three-wire system is used for distribution, as six wires would then be required, forming six circuits that must be kept balanced.

The two-phase system is subject to the same objections unless the two phases are used separately for lighting, in which case we have the complication equivalent to twice the number of generators and feeders.

For good regulation and simplicity, the single-phase system cannot be equaled by any multiphase system.

The so-called monocyclic system is a modified two-phase system in which current is distributed for lighting on a single-phase circuit only, and a third wire carries current in quadrature to the first, which, in connection with the first, is transformed to a three-phase relation wherever it is desired to operate motors. The regulation of this system can be made almost as good for lighting as the single-phase, and can be as simply effected. The third wire adds complication, but no balancing is required, as all the lighting is done from single phase on two wires. If low-tension, three-wire distribution is attempted with this system, a fourth wire must be used for power distribution.

A system practically the counterpart of the monocyclic, is the three-wire, two-phase system, in which the lighting is all done on one single-phase, and a third wire is used in conjunction with the other two for power. It is handled in exactly the same manner as the monocyclic system, the only practical difference being in the relative potential of the quarter-phase circuit. In the monocyclic, the quarter-phase element of the generator winding is one-quarter the potential of the main winding, giving between the power line and the main lines a pressure of fifty-five per cent of that between the main lines themselves. In the special form of three-wire, two-phase, the quarter-phase element of the generator winding is equivalent to one-half of the main winding, which causes a pressure between power line and main lines seventy-one per cent of that between the main lines. For power distribution, this system requires slightly less wire than the monocyclic. Figure 3 shows diagrammatically the arrangement of this system used in connection with the special method of distribution already described. The diagram shows a system of two-wire mains for lighting to which might be applied, of course, the Edison three-wire system. The motors used would most naturally be of the two-phase type although three-phase motors may be used with equal facility by the method of transformer connections devised by Mr. Scott.

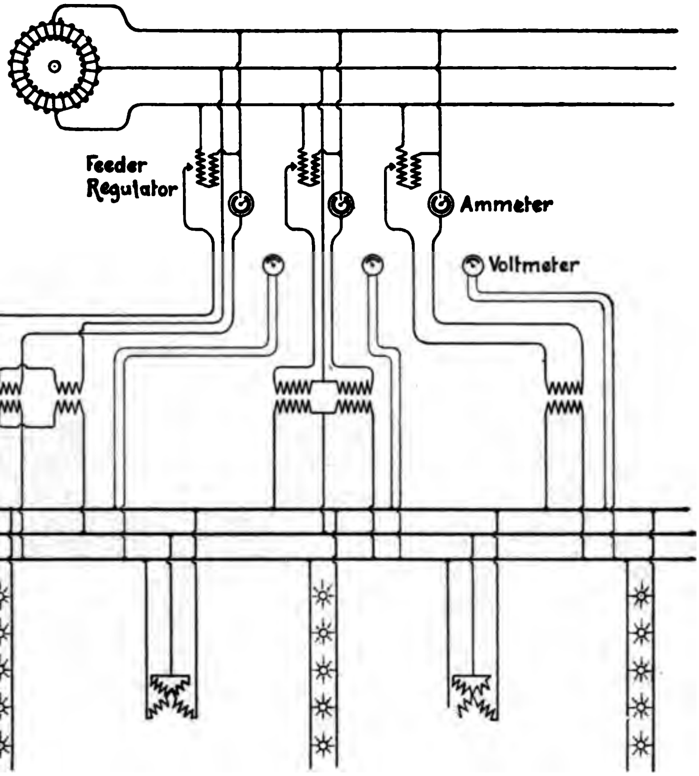


FIG. 3. THREE WIRE TWO PHASE SYSTEM
with single phase lighting.-High pressure Feeders & low pressure distribution.

It can be readily seen that while these systems are much better adapted to general station distribution than the two-phase or three-phase, they still lack the simplicity of the single-phase, and both require more wire. Fortunately, we can now obtain single-phase motors which equal the multiphase and direct-current motors in efficiency and almost all desirable points. They start readily with load and may be operated with variable speed; in fact, they equal the direct-current shunt motor in all points, excelling it in efficiency and simplicity.

We can meet the direct-current advocates on the power question, therefore, on at least an equal footing, save only one application met in central-station practice; namely, the operation of high-speed elevators. The alternating-current motor, multiphase or single-phase, cannot be controlled for this work as readily as a compound series, direct-current motor. It has taken several years, however, to perfect the mechanism for the control of direct-current elevator motors. Give us the same time, and we will do it with alternating current. This field for power has only of late been opened to direct-current stations, and it is yet a question for debate as to whether it is a paying one.

SPECIAL APPLICATIONS OF CURRENT

There are many special applications of current met with in practice, most of them bringing a small return, such as electro-plating, electro-cautery, charging small storage batteries, electric heating and cooking, etc. The first three require low-potential currents, and are economically effected only by motor generators or rotary transformers. It is evident that this transformation can be accomplished as readily with alternating current as with direct current. Electric heating and cooking are as yet luxuries, and cannot be depended on for much revenue. They can be done with equal facility by alternating current.

STORAGE BATTERIES

Here we come to the direct-current advocate's last and greatest stronghold. To this he retreats with great confidence of safety. We may ask first whether storage batteries have yet been proved to be a valuable adjunct to the central station, cost and maintenance considered. It is true they are being tried by several large stations, and we watch eagerly for the results. They equalize the station load to a greater or less degree, and cut down the generator capacity for the peak. Are they, however, cheaper than generators, engines and boilers of the same capacity? Are the losses in transformation less than the cost of a few more attendants? Is their maintenance less expensive than that of generating apparatus? These questions cannot as yet be answered in the affirmative. But if the battery man's most sanguine hopes be realized, what then? If rotary transformers are good enough for the direct-current man to use to change the direct current to alternating current, transmit a good proportion of his load to a distance and transform again to direct current, why should not the alternating-current man use them to charge his batteries and then to transform their output back to his pet form of current? Loss in transformation, do we hear some one say? Not any more than with our contemporaries' long-distance transmission system, and, in this instance, they are small and unimportant, we are told. There is at least one station in the country where storage batteries are being used in this way, and I believe with success, as storage batteries go.

Have our direct-current friends anything more to bring forward? Or have we forced their last position? Well, we will declare a truce, and acknowledge that they fight bravely. We have learned as much from them as they can learn from us. If we had been as quick to acknowledge their beautifully designed distributing details and applications as they have been to appreciate a few of the advantages of our current, we might have been nearer together, or even hand in hand, long ago. As it is, we are both working to the same end, and our paths must join sooner or later as they converge.

Before closing, I wish to recapitulate a little, and draw your attention more forcibly to the flexibility of the alternating-current system. We all know of the many applications to which this current is now put, and what we have described here is, most of it, not new to many of us. The use of the rotary transformer has been widely talked of and described for the last two years. The facility of operating lines at any potential desired, through the means of step-up and down transformers, is no longer an experiment. Multiphase motors are familiar to all, while single-phase motors have been much talked of and written about, and failures have, time and again, followed boasted success. Many of us, however, have within the last year seen them quietly at work, thoroughly tamed and domesticated. One large station is using them extensively, and is so thoroughly convinced of their success that it has discarded all notion of using multiphase distribution, although it is using generators that can be operated two-phase if desired. Direct-current motors are being rapidly replaced by these single-phase motors to secure uniformity of system.

Arc lamps have been familiar to us on alternating-current circuits for some time, and the alternating current, enclosed, long-burning arcs are now numbered by the thousands. Street lighting is still, however, in most places done on the direct-current series system, and even the largest machines yet built for this purpose are very small in comparison with our large direct-connected generators.

The great desideratum in central-station practice is to be able to employ one system for everything. All current for all classes of service should be supplied from but one type of generator, be this direct-current or alternating-current. In this way, only, can the maximum output be accomplished from a given investment in machinery and apparatus, and the greatest economy in operation secured. This has been accomplished in many stations where a limited range of service is to be provided. Arc lighting has, of all, been the most troublesome to provide for. How shall we operate our arc lamps from our incandescent lighting system, has been the anxious inquiry. The constant-potential arc lamp has answered this question for commercial lighting, but city street lighting cannot be so easily provided for. The Edison companies have done a limited amount of this from their three-wire system, but this can be done to advantage only in districts where mains have been provided for commercial lighting. For extended arc lighting, the small series machine with its belts and clutch pulleys still holds the fort.

I am able to state, however, that one large company has recently solved the problem to its entire satisfaction. This company furnishes 2,600 street lamps to the city, lighting some 300 miles of street. These were operated by a small army of series arc machines.

They were installed by a company that was acquired by purchase by the one first mentioned. As this company had long since adopted alternating current for its entire distribution, it was extremely desirable to be able to operate these city lamps from its large direct-connected alternators, thereby saving in fuel, attendance, floor space and reserve investment.

After a few months' trial of an experimental circuit with alternating current, it was found perfectly feasible to operate the same direct-current lamps, slightly remodeled, on the same circuits of sixty or eighty lamps in series. A system of this kind was, therefore, adopted and the company now has 2,300 of these lamps in regular operation by alternating current in this way. The circuits are each provided at the station with a regular step-up transformer of a maximum capacity of 4,000 volts and ten amperes, and the feeders to these transformers are treated on the switchboard in the same way as the feeders for incandescent lighting. It is quite usual for one generator to carry 2,000 of these lamps. The lighting is satisfactory to the city and the lamps give better service than when operated by direct current. There has been a very marked saving in fuel and attendance. The indicated horse-power per arc lamp is considerably less than with the direct-current arc lamps operated in the usual manner. Figure 4 shows this system in diagram.

I know of no other place where this is being done, and it stands as a very pronounced example of the flexibility and adaptability of alternating currents.

There have been a great many problems in the operation of large alternating-current stations that have been discouragingly difficult of solution. The handling of high potentials on switchboards, the operation of generators in multiple, with facility, and scores of more or less important difficulties, have, one by one, been surmounted, the burden of the work usually falling on a few of the pioneer stations.

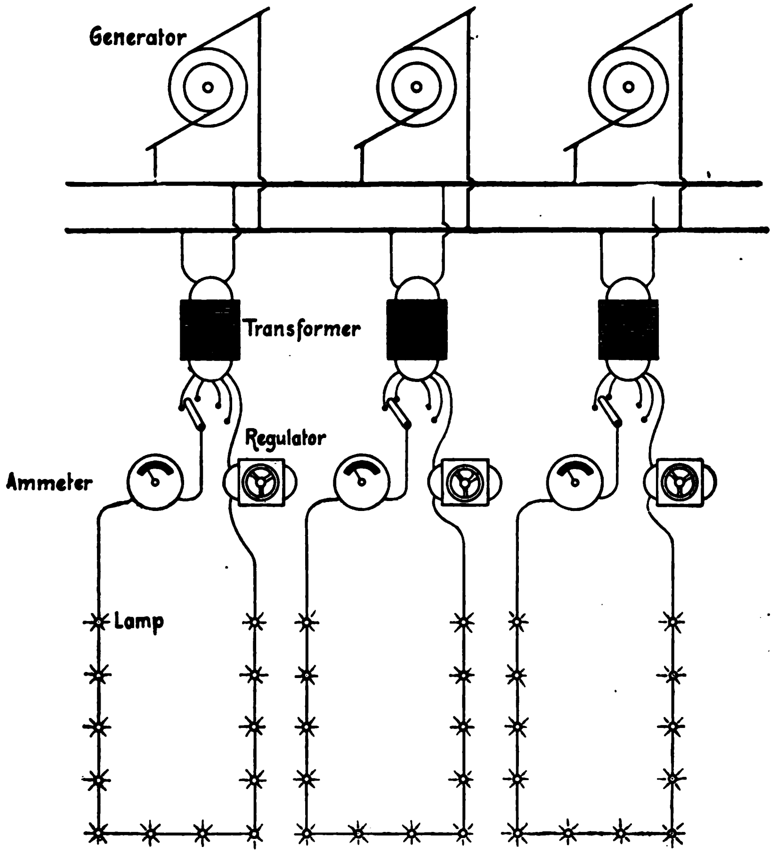


FIG. 4. A.C. SERIES ARC-LIGHT SYSTEM.

In summing up, we find the following marked features in which the alternating current, properly installed, has been shown to have pronounced superiority over the direct current:

Highest possible efficiency of distribution and operation.

Best regulation.

Largest territory desired readily supplied from one station.

Comparatively small cost of feeders, effecting enormous saving in investment.

Least cost of real estate.

Cost of installing and operating sub-stations entirely voided.

The only system in which all classes of service can be supplied from one type of generator.

Greatest flexibility.

In closing, I wish to thank my friends and co-laborers of the direct-current faith, from several of whom I have had the pleasure of learning much that has proved of great value to me.

THE PRESIDENT: I will ask Mr. Ferguson to read his paper on general distribution from central stations by direct currents.

Mr. Ferguson read his paper, as follows:

GENERAL DISTRIBUTION FROM CENTRAL STATIONS BY DIRECT CURRENTS

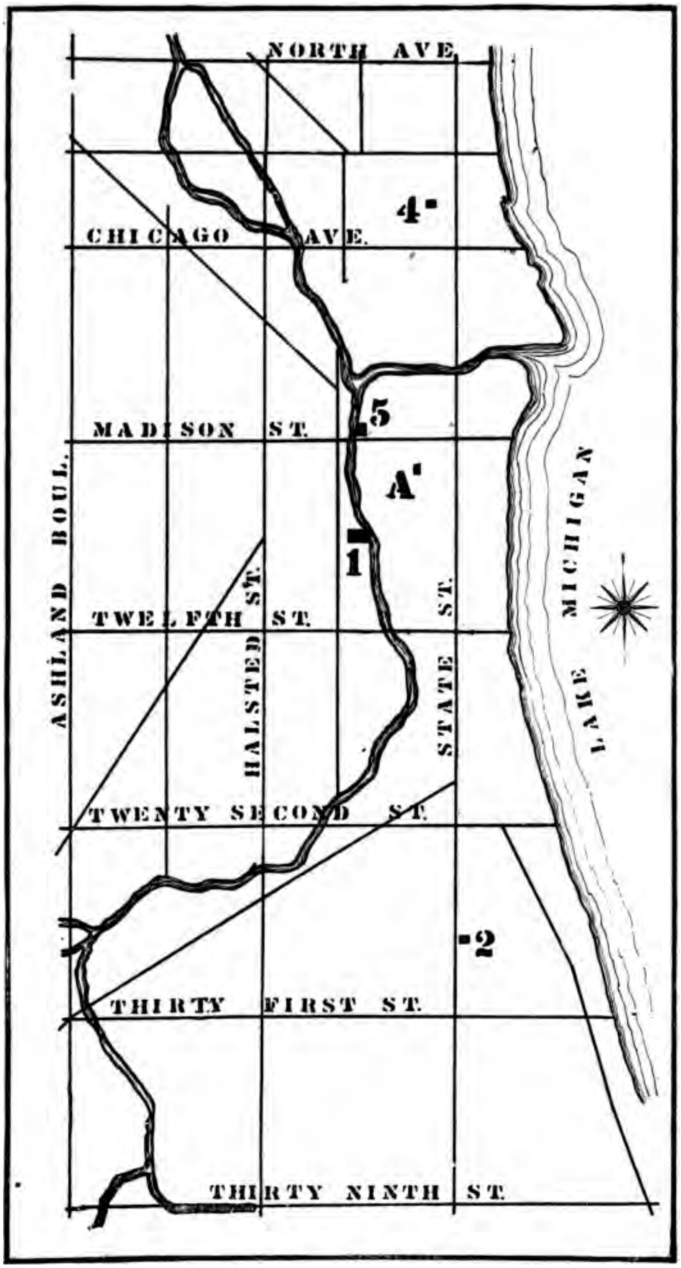
Mr. President and Gentlemen of the National Electric Light Association:

The subject of central-station distribution by direct currents is one that is so familiar to many of you that I hesitated when asked to write this paper, feeling that it would be difficult to present to you any new thoughts or experiences, so I trust you will pardon me if in the attempt to precipitate discussion and bring to the attention of the meeting the ideas and experiences of others, which is, after all, the object of my paper, I may trespass upon ground previously explored.

Nor do I wish to be construed as advocating blindly the general use of direct currents under all conditions for both transmission and distribution of electricity for lighting and power purposes in cities and towns, for records will, I think, clearly show that the writer was the first of the so-called Edison central-station men (who have represented the direct-current idea in central-station lighting) to advocate the introduction of the alternating current as a means of effecting important economies in the operating of the direct-current distribution systems, and also vastly extending their field of operation, which, without the combination of alternating currents, might have remained, despite their distinct advantages, unfortunately limited to a comparatively small and closely-populated area.

The general design of the modern direct-current central station and its equipment has been fairly well established within the past five years, and while it was originally the custom to erect the generating stations as nearly as possible in the electrical centre of the city or town, it is now generally conceded that direct current may be more economically distributed from a condensing station situated even a mile distant from the electrical centre than from a non-condensing station located at the electrical centre of the city; and it has been further demonstrated that the former practice of building many central generating stations in various centres of distribution in cities is to be supplanted by the use of one or two large condensing stations, generating direct current for distribution throughout the business district if the station be within one mile of the electrical centre of the district, and alternating current for transmission to sub-stations located at the electrical centres of districts more remote from the main generating station. In some cities, water for condensing purposes may not be easily obtainable within a distance of one mile, and the location is then merely a question of total cost of land, building, and transmission lines to the various distributing stations; proper consideration being given, of course, to the limitations of line voltage and insulation.

In order to show the workings of the first-mentioned type of modern direct-current central-station systems, I will explain in a general way the method of distribution employed in the system of the Chicago Edison company, which I think fairly represents the latest development in direct-current distribution, and will leave the explanations of the methods of direct-current distribution in other cities to the representatives of the companies operating them.


NORTH AVE.
4
CHICAGO AVE.
5
MADISON ST.
A'
1
TWELFTH ST.
ASHLAND BOUL.
HALSTED ST.
STATE ST.
LAKE MICHIGAN
TWENTY SECOND ST.
2
THIRTY FIRST ST.
THIRTY NINTH ST.

The system of distribution is a solid network of underground conductors on the three-wire system, extending from North avenue to Thirty-ninth street, a distance of six miles north and south, and from Lake Michigan to Blue Island avenue, a distance of one and one-half miles east and west. The entire network is continuous from end to end, and is supplied at present from four central stations, all connected in parallel through the network and each feeding into it. The two large stations located at Harrison street and Washington street on the Chicago River, and known as stations No. 1 and No. 5, respectively, are condensing plants, while the stations on the north side and south side, located at North Clark and Oak streets and Wabash avenue and Twenty-seventh street, known as stations No. 4 and No. 2, respectively, are non-condensing.

The total current furnished to the network at the time of maximum load of the system in the winter of 1897 was 50,730 amperes, and is divided as follows:

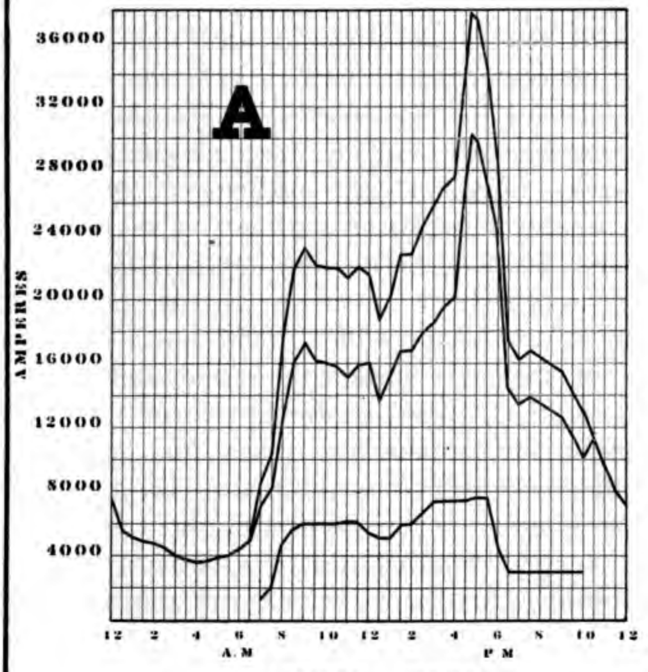
	Amperes	Per cent of total
Station No. 1	35,600	70.2
Station No. 5	7,600	15.0
Station No. 2	3,400	6.7
Station No. 4	4,130	8.1
	50,730	100.00

The total low-tension, direct-current kilowatt-hours' output for the stations for the fiscal year of 1897 was 15,255,466, divided as follows:

	Low-tension kilowatt-hours	Per cent of total	Maximum station voltage	Yearly average station voltage
Station No. 1	11,335,618	74.3	149.	126.2
Station No. 5	2,314,473	15.2	142.5	129.6

Station No. 2..	808,158	5.3	125.0	119.0
Station No. 4..	797,217	5.2	123.5	120.1
	15,255,466	100.0		

The pressure at the feeder ends throughout the system is maintained at 115 volts on each side of the three-wire system. Although the maximum-station pressure is 149 volts, the average pressure of all stations for the year is 126.2 volts, giving an average loss of pressure of 11.2 volts or 8.8 per cent, which means an average yearly efficiency of distribution of



AMPERE CURVE
DIST. NO. 1

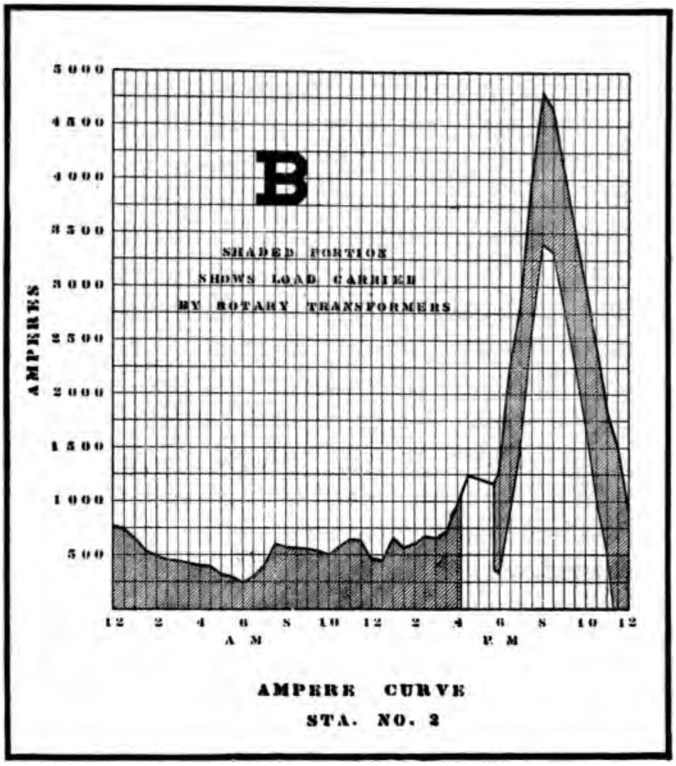
91.2 per cent from the station switchboards to the customer's meter.

The centre of distribution in the business district of the city is at Adams street, between Clark and La Salle streets. Station No. 1, which, as has been shown, furnishes 74.3 per cent of the total low-tension output, is located on the Chicago River at Harrison street, 3,340 feet distant from the centre of distribution at Adams street. Station No. 5, which furnishes fifteen per cent of the total low-tension output, is located on the Chicago River at Washington street, and is 4,500 feet from station No. 1, and 3,000 feet from the Adams street sub-station. These two stations furnish all the low-tension output for the district bounded by the river on the north, Harmon court (approximately) on the south, Lake Michigan on the east and the river on the west. They also furnish all the energy for the entire low-tension system of the city during the hours from midnight until dusk the following afternoon, and a portion of the output of districts No. 2 and No. 4, from dusk until midnight daily; and ultimately they will furnish all of the output of the territories mentioned, and all of the energy required for alternating transmission lines into the outlying districts of the city and its suburbs.

The load curves "A" here shown, indicate the amperes furnished in district No. 1, by stations No. 1 and No. 5, the small lower curve representing that delivered by station No. 5, and the lower large curve showing that delivered by station No. 1, and the upper curve representing the total amperes delivered to district No. 1.

The distribution of current from these two stations to the underground net work is as follows:

From station No. 1 to the Adams street substation is laid an immense trunk line known as the Adams street trunk line, having a total cross-sectional area of 66,000,000 circular mils, 28,500,000 circular mils being ordinarily connected on the positive and negative sides and 9,000,000 circular mils in the neutral. The length of this trunk line is 3,340 feet, and is made up of fifteen special Edison tubes, each 3,000,000 circular mils area, laid directly in the ground, and fourteen 1,500,000-circular-mils stranded rubber-insulated, lead-covered, and juted cables drawn into cement-lined iron ducts. The trunk line, on leaving station No. 1, goes down a shaft sixty feet, thence through a brick tunnel built especially for it in the river bed to the east side, where it rises again in another shaft sixty feet into the tunnel house, where a small switchboard is located. The portion of the trunk line in the shafts and tunnels, which is 430 feet in length, is made up entirely of cables; of these forty-five are 1,000,000-circular-mils Siemens jute-insulated and fourteen are 1,500,000-circular-mils General Electric rubber-insulated, leaded, asphalted and iron-armored submarine cables, each supported on iron racks. Where the cables hang vertically in the shaft, the cable is supported by the iron-armored sheathing clasped between iron plates on a heavy cast-iron ring. The copper conductors thus hang in a sort of basket, the strain being distributed throughout the length of the cable. At the tunnel house the forty-five Siemens 1,000,000-circular-mils cables connect with fifteen 3,000,000-circular-mils, single-pole Edison feeder tubes, and, together with the fourteen 1,500,000-circular-mils cables, are mounted on racks in a large subway, into which the duct line enters about two hundred feet east of the tunnel house. At intervals of about five hundred feet, manholes are built in the Edison tube portion, as well as in the conduit portion, of the trunk line, thus affording a quick means of locating low-insulation points as they develop. Each of the tubes and cables is provided with an amperemeter at station No. 1, and with switches at both ends, so that they may be completely disconnected from the system in case of trouble. Two of the 3,000,000-circular-mils tubes are provided with throwover switches and arranged so that they may be quickly connected either to the positive or neutral or negative



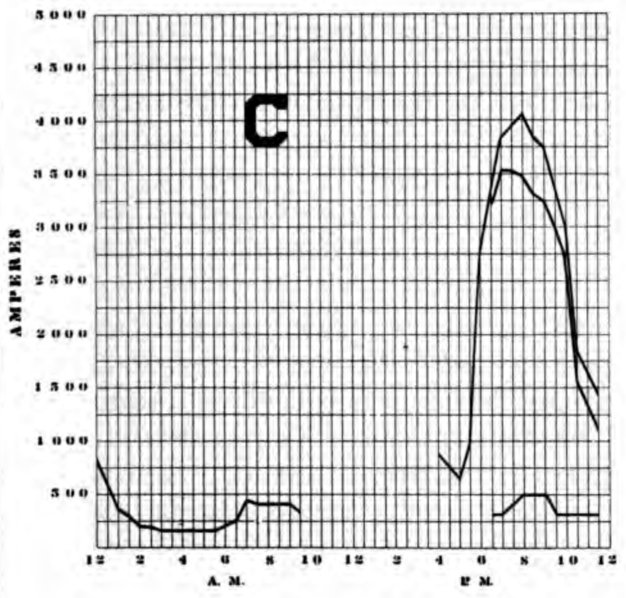
AMPERE CURVE
STA. NO. 2

or neutral at will. All of the cables are provided with throwover switches on both ends, so that they may be operated either as positive or negative at will, thus providing for any possible contingency that may arise. At the Adams street sub-station the trunk line feeds into the main 'bus-bar in the distribution room, and from the switchboard forty-two feeders radiate to various points in the business district, ranging in size from 250,000 circular mils to 1,000,000 circular mils, and in length from 290 feet to 2,831 feet, the average size being 485,000 circular mils, and the average length of feeder 1,373 feet.

The maximum current in amperes carried over the trunk line and distributed from the Adams street sub-station last December was 34,400 amperes, the maximum loss of pressure on the trunk line being 12.4 per cent, and to the customers' meter 22.8 per cent, the distance to farthest feeder end being 6,171 feet. In addition to the current furnished to the trunk line, station No. 1 also delivers from its main 'bus-bar current to the two 1,000,000-circular-mil feeders that feed into two points in the southern portion of the business district. One of these feeders, terminating at Wabash avenue and Harrison street, is 3,800 feet in length, and carries, with maximum station pressure, 780 amperes on each side; the other, terminating at Eldredge court and State street, is 4,800 feet in length, and carries, with maximum station pressure, 620 amperes on each side. The supplying of district No. 1 by station No. 5 is done in much the same manner as that just described by the two feeders from station No. 1 into the southern portion of the district. From station No. 5 eight feeders, varying in size from 400,000 circular mils to 1,000,000 circular mils, and in length from 2,175 feet to 4,445 feet, terminating at different points in the northern section of district No. 1, deliver a total of 7,600 amperes at maximum station pressure of 140 volts, the amount of current furnished during the run being only enough to maintain standard system pressure at the feeder ends, the curve of station voltage following very closely that of station No. 1..

Station No. 2, which is now really a rotary-transformer sub-station, is 17,500 feet from station No. 1, and 14,300 feet from Adams street sub-station. The load diagram "B" shows the amperes delivered to district No. 2, the cross-hatched portion representing the current furnished through the rotary transformers and the unshaded portion representing the current furnished by the dynamos in station No. 2, the dynamos and rotary transformers operating in parallel on the three-wire system. The upper curve shows the total amperes delivered to district No. 2.

Station No. 4, which now operates only from dusk till midnight, and will later become a sub-station, is 11,500 feet from station No. 1, 9,000 feet from station No. 5, and 8,000 feet from Adams street sub-station. The load diagram "C" shows the amperes delivered to district No. 4. The portion of the curve from midnight until 3.30 p. m. on the winter day and until 6.30 p. m. on the summer day is furnished from district No. 1 through the inter-connected underground network, the district No. 4 being, during these hours, merely an extension of district No. 1, and having no distinct supply delivered through its own switchboard. From dusk till midnight the generating plant in station No. 4 is operated, and the current is delivered as shown by the next to the highest curve on the diagram, the low curve marked No. 5 representing the amperes furnished by station No. 5 to district No. 4 over a direct-current tie line between the switchboards of the two stations. The tie line is made up from one feeder running out of station No. 5, originally feeding into district No. 1 and now connecting, by means of river cables, with a feeder out of station No. 4, which formerly fed into the district at a southern point. This tie line is also used on dark days to keep up the pressure in district No. 4 by connecting onto the main 'bus in station No. 5 and allowing it to take a small current and deliver it to station No. 4 switchboard, thus relieving the network



AMPERE CURVE
STA. NO. 4

between districts No. 1 and No. 4 of some of the work. Between the hours of midnight and eight o'clock in the morning there is only one low-tension, direct-current generating station operating (station No. 1), supplying direct current to district No. 1, and through the network to district No. 4.

District No. 2 is supplied from station No. 1 by means of a converse rotary transformer connected to the 250-volt direct-current 'bus-bars, converting to three-phase alternating current at about 160 volts. By means of step-up transformers, this is raised to 4,500 volts and at this pressure the energy is transmitted by three-phase underground transmission line to station No. 2, where it is reduced by step-down transformers to about eighty volts and converted by means of rotary-current transformers to direct current at about 115 volts.

For the permanent conversion of station No. 2 into a sub-station, a pair of special 200-kilowatt generators are being installed, directly coupled to the existing 600-horse-power, triple-expansion engines in station No. 1. Each generator is provided with a commutator and a set of three collector rings, and is designed to deliver from the same armature direct currents and three-phase alternating currents; the direct-current sides of each pair of machines being connected in series to form a three-wire unit, and the alternating-current sides, after passing through transformers stepping up to 4,500 volts, being connected in multiple. The alternating current from these machines will be taken to supply the transmission line to station No. 2, and the balance of the capacity of the machines will be delivered directly into the main direct-current 'bus-bar of station No. 1, thus keeping the unit operating at full load and maximum efficiency during its run. The peak of the load in district No. 2 arrives later than the peak of district No. 1, so that the same investment in steam and electrical machinery may be employed to take care of a portion of the peak in both districts, these special generators constituting a reserve or surplus for the direct-current equipment of station No. 1.

Lest I might wander from the subject of the paper, I shall not now dwell further upon the question of transmission of energy by alternating currents, although it plays an exceedingly important part in the distribution of electricity by the Chicago Edison company.

Uniformity of pressure throughout an incandescent electric-lighting system is absolutely essential to commercial success. To accomplish this, different methods have been proposed at different times. It often happens that the original plan of distribution, laid out by the constructing engineer, does not meet the requirements after several years' growth of the business; for in all cities lighting business may localize at certain special points, and so demand a remodeling of the existing system of conductors, or require some means of correcting the inequalities of pressure that are due to the unevenly-distributed load.

In the Edison systems built prior to 1890, it was customary to introduce in series with each feeder a resistance box with capacity to carry the entire current of the feeder and of resistance much greater than that of the feeder itself. The resistance box is commonly known as a feeder equalizer. From the end of each feeder where it connected with the mains, a set of pressure wires was run back to the station and there connected to pressure indicators. The method of regulating was to designate the feeder supplying the most important district in the system the standard feeder, and to keep its pressure constant, say 110 volts. Each pressure indicator of the other feeders was differentially wound, so as to receive the pressure of the standard feeder as well as the pressure of its own feeder. When there was any difference of pressure between the standard feeder and a given feeder, the latter's indicator needle would deflect to one side or the other according as the pressure on that feeder was higher or lower than the standard, and if the equal of the standard the indicating needle would stand in the centre. If, then, any indicator showed that its feeder was low in pressure, some resistance would be cut out of its feeder equalizer, and, the resistance diminishing, the volts loss on the feeder would then become less, and thus the feeder could be brought to the same pressure as the standard. If the pressure of the feeder were high, the operation would be the reverse. With this method of regulation, the entire output of the station must be at such pressure at the station switchboard as will permit the delivery of the correct pressure at the end of that feeder the product of whose load and resistance is greatest in the system. There are some large stations in America operating to-day on this plan of regulation, notwithstanding that it is an expensive and troublesome one. Another method of regulating, which may be employed where the load is fairly well distributed, is by cutting out the feeders that are high and forcing the current to travel through the remaining feeders and the mains, thus increasing the fall of pressure to the end of the feeders that were formerly high. The only economical and safe way to regulate in a city where the distances are not abnormally great, and where the load is fairly well distributed, is to so design the conducting system that it will be self-regulating, that is, so that it will require no change of the resistance of feeders or anything of the kind. A good conducting system should have an ample number of feeders reasonably close together, and the connecting mains should be of generous cross-sectional area.

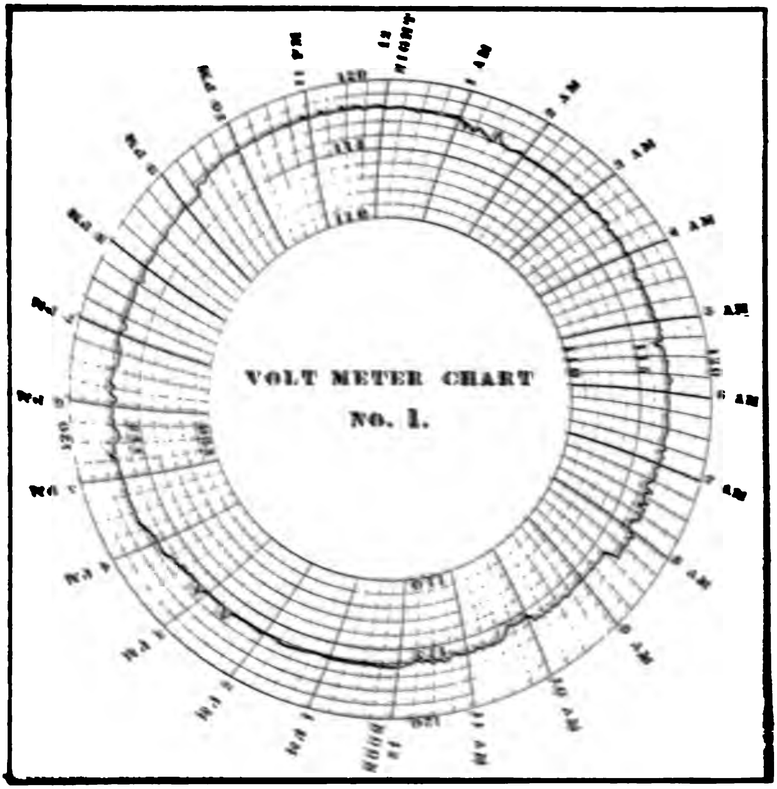
A valuable adjunct to a station, where there are one or two straggling feeders of great length so located that they cannot be interconnected with the general system so that they may be benefited by such connection, is what is known among the Edison companies as the "booster." The "booster" is a direct-current dynamo wound for a large current and low voltage, and is used for raising the pressure of the station and of the feeders which are ordinarily low. The "booster" dynamo should be series-wound and so designed that its voltage will be proportional to the current passing through it, the speed remaining constant. It is connected in series with the feeder whose pressure is to be raised, and is belted to or directly connected with a motor which drives it at the speed for which it is designed. Its action is as follows: The current passing out on the feeder also passes through the field and armature of the "booster" dynamo, and an electromotive force is thus added to that already existing on the feeder due to the dynamos of the general system. As the load on the feeder increases, the electromotive force of the "booster" dynamo increases proportionately, and adds to that of the feeder, thus overcoming the loss of pressure due to the increased current in the feeder, which enables the feeder to deliver the proper pressure at its mains. The "booster" may also be employed to raise the pressure of a number of feeders whcih are connected to an auxiliary 'bus-bar. In this case, the "booster" would be connected between the main 'bus and the auxiliary 'bus, and would carry all the current of the auxiliary 'bus, raising the pressure of it as its load increases, and decreasing as the load decreases, as described in the case of the single feeder. In some central stations two or more potentials or pressures are used, certain dynamos working on a 'bus-bar at one pressure and the other dynamos working on another 'bus-bar at different pressures. This method is only economical when the dynamos can be worked very near the maximum load, which is not often the case. In some cities the dynamos in central stations, or machinery or storage batteries in sub-stations, feed into one general system at different points, each station or sub-station operating at such pressure as will deliver the same voltage at the feeder end of the mains. This is, without doubt, the method to be recommended as giving the best efficiency and assuring reliability of service throughout the system. With the method proposed, in case of accident to any one station, either by fire or lack of water supply, the whole system will not be shut down, but each station will take its share of load which comes from the shutting down of the disabled station.

Municipal legislation in all large cities requires, and very justly so, that the wires for the distribution of electricity for lighting and power purposes should be laid under ground. The Edison companies throughout the country use a standard system of underground, the mains and feeders consisting of japanned iron pipe in which are three solid copper wires or rods insulated from each other and from the iron pipe by an asphaltum compound. These pipes or "tubes," as they are commonly called, are twenty feet in length, the copper conductors projecting three inches on each end, making the total length of each pipe twenty feet six inches. The copper conductors are connected together by means of a flexible coupling, composed of a stranded copper cable about eight inches in length, and having copper terminals on either end, and which are provided with a circular opening of such diameter as will permit the reception of the copper conductor of the tube. The copper terminal is heated by the flame from a blow lamp, and the copper conductor is soldered into the terminal. After the three couplings are connected, an iron-ball clamp is bolted on to the tube near the end, and a cast-iron, oval-shaped coupling box is laid over the copper joint and fastened together by bolts and nuts. The coupling box is then filled with hot insulating compound, and after this has settled by cooling, the box is again filled and the opening covered by plugs. At each street intersection these tubes enter a junction box. The junction box is a cylindrical cast-iron box, in the centre of which is a cast-iron upright standard carrying three rings of flat copper bar. To one of these rings all of the positive conductors are connected, to another ring all the negative conductors, and to the remaining ring all of the neutral conductors are connected in a similar manner. Many of the junction boxes are fed by a feeder direct from the central station, the feeder, when Edison tubes are used, being laid in the same manner as the mains before described. The feeders in a three-wire system consist of three conductors, as in the case of mains, with the exception that one conductor, which is used as a neutral, has usually one-third the area in cross-section of either of the two other conductors. Feeder tubes are made in various sizes, from 250,000 circular mils to 3,000,000 circular mils. Each feeder tube also contains three small insulated copper wires, which are connected in each coupling box to the corresponding wires in the next tube, thus making a continuous circuit from the feeder end in the junction box at street intersection back to the station. At the generating station these wires connect with a pair of voltmeters, and at the end of the feeder they are connected through fusible strips to the copper rings in the junction box, thus giving in the station the pressure or difference of potential at the feeder end. By means of the junction boxes, the system becomes one grand network of conductors, connected in multiple and fed at many points by feeders from the central station, similar to that of a well-designed gas or water system in a large city. By means of this network of mains the electrical pressure is equalized throughout the system, and the current is distributed properly among the feeders. Every mechanical and electrical detail of the system is very carefully worked out and absolutely interchangeable, and it is without question, when cables are used for the feeders, the most complete, most easily operated, and most permanent underground system yet devised for the distribution of electricity for large cities using a direct-current system of 500 volts and under. With this system the customers are almost absolutely certain to have continuous service, as they are fed from two points under ordinary conditions; and should the main in their block burn out, it is nearly always possible for the company to feed the customers from one or another junction box. The method of coupling affords a perfect house-to-house system of distribution, and renders the placing of services a very easy and simple matter. The system is very easily laid down, and its maintenance compares favorably with other methods of distribution.

The maintenance of good pressure regulation at the customer's meter is very much more easily effected with an interconnected direct-current distribution, such as has been described, than with the ordinary alternating-current central-station system, such as has been exploited in this country.

Owing to the parallel operating of direct-current dynamos and distribution systems, the fluctuations in the pressure, due to change over from one machine to another, so prevalent in the ordinary American alternating-current central station, and so annoying to customers, are eliminated, and a carefully-operated direct-current central station should show a pressure chart with an average deviation from the mean of less than one volt. It is possible, of course, and often the careless practice in direct-current stations, to have bad fluctuations of pressure at the times of change over, and also irregularities at other periods, but there is absolutely no excuse for their existence in a well-operated and well-planned direct-current system.

The parallel operating of the generators greatly simplifies the maintaining of uniform pressure regulation at the lamps, since when several units are connected to the common 'bus-bar the regulation for the entire system may be effected by careful attention to one unit; whereas in alternating-current stations, where the generators do not operate in parallel, it is necessary, in order to even approach the uniformity of pressure regulation that exists in direct-current systems operating in parallel, to regulate the pressure accurately on each unit, which is seldom done in practice. Besides the better regulation possible with parallel operating of the dynamos, a further distinct advantage is derived from the economy effected by proper division of load among the units in the stations; this being particularly marked when the distribution systems are also interconnected. Each unit, irrespective of size, may be usefully and efficiently employed at the period of maximum load, and the amount of idle or uneconomically employed investment is reduced to a minimum.



To illustrate the comparative accuracy of regulation obtainable in an interconnected, direct-current system, and in the ordinary type of independent-circuit, alternating-current system, let us refer to the pressure charts shown in the enclosed sheets.

Chart No. 1 represents the pressure for twenty-four hours on the direct-current distribution system in the business district of Chicago; the average deviation from the mean pressure is less than one volt.

Chart "H" represents the pressure on one of the circuits of a single-phase, house-to-house-transformer, alternating system in Chicago.

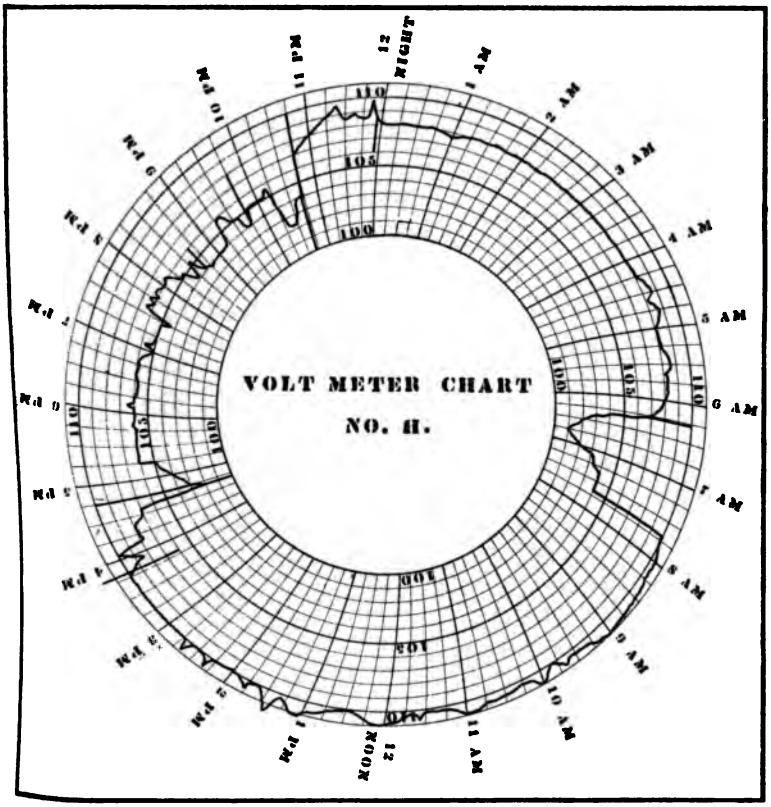
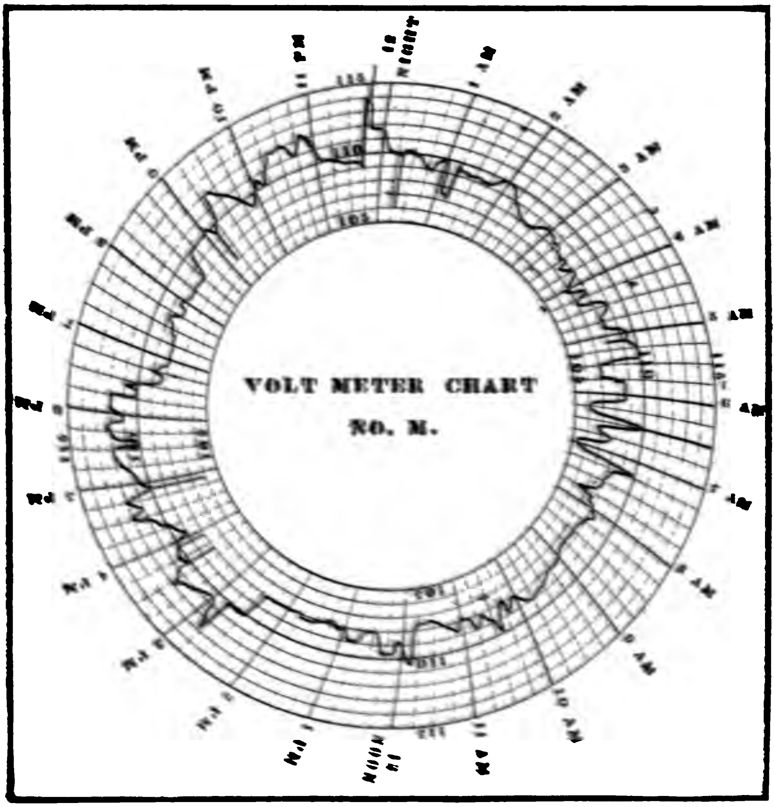


Chart "M" represents the pressure regulation of an alternating-current system on a long avenue, where are used primary feeders with four fifteen-kilowatt transformers, the secondaries in multiple on the three-wire system.

If the engineer designing a system employing alternating current in the distribution, expects to obtain first-class pressure regulation, he must follow those lines laid down by the engineers who have developed the modern direct-current distribution system. The distribution system of mains should be interconnected, forming one grand network of conductors with large transformers, located at points where feeders would terminate if it were a low-tension, direct-current system, and to these transformers should be brought the

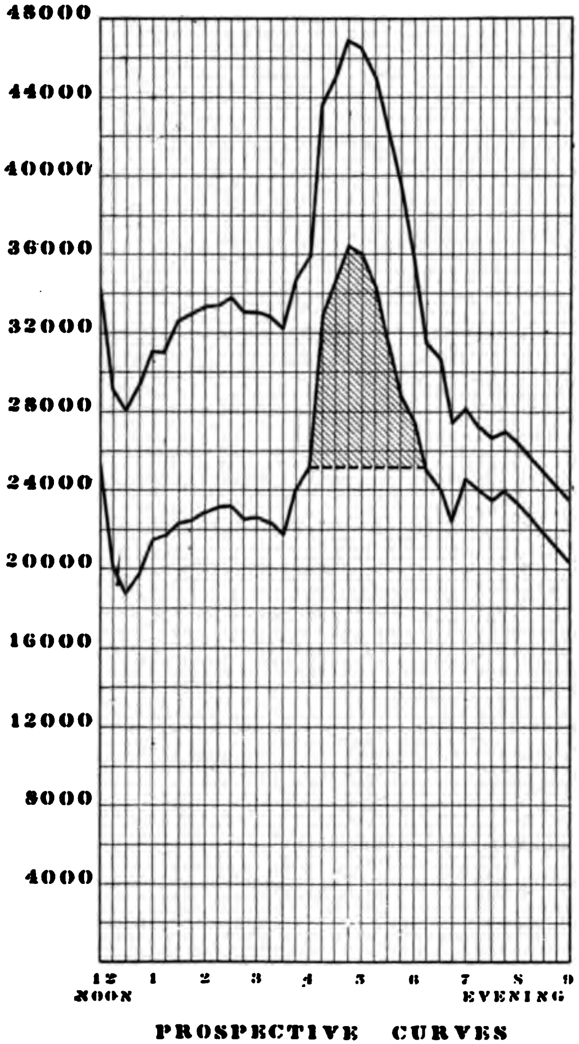


primary feeders from the central station, provided with boosting transformers or induction regulators. Pressure wires from the secondaries of the transformers should be brought back to the station, so that the pressure on the ends of the mains may be known and properly controlled. Such a system will be described to you in detail by Mr. Wagner, and I am sure he will agree with me when I say that the single-phase, house-to-house-transformer, separate-circuit, alternating-current system, such as has been generally exploited in this country, has nothing to recommend it to the central-station manager, either from a purely engineering or financial standpoint, although it has fulfilled its mission as a pioneer in the introduction of electric lighting in scattered districts.

One of the advantages to be derived from the use of direct-current distribution, as distinct from alternating-current distribution, is the employment of storage batteries. They may be adopted for use in various ways: In sub-stations in outlying districts where the load-factor of the district is very small; in the central stations themselves, to deliver the entire output during period of minimum load; at the centres of distribution, for discharging during the peak, and as auxiliaries in rotary-transformer sub-stations for discharge use at the time of the maximum load in the main central station. In addition to any one of the various ways in which the battery may be employed, it always acts as a reserve, guaranteeing the consumer good service, in much the same manner as a bank surplus is a guaranty to the depositors in cases of financial emergency.

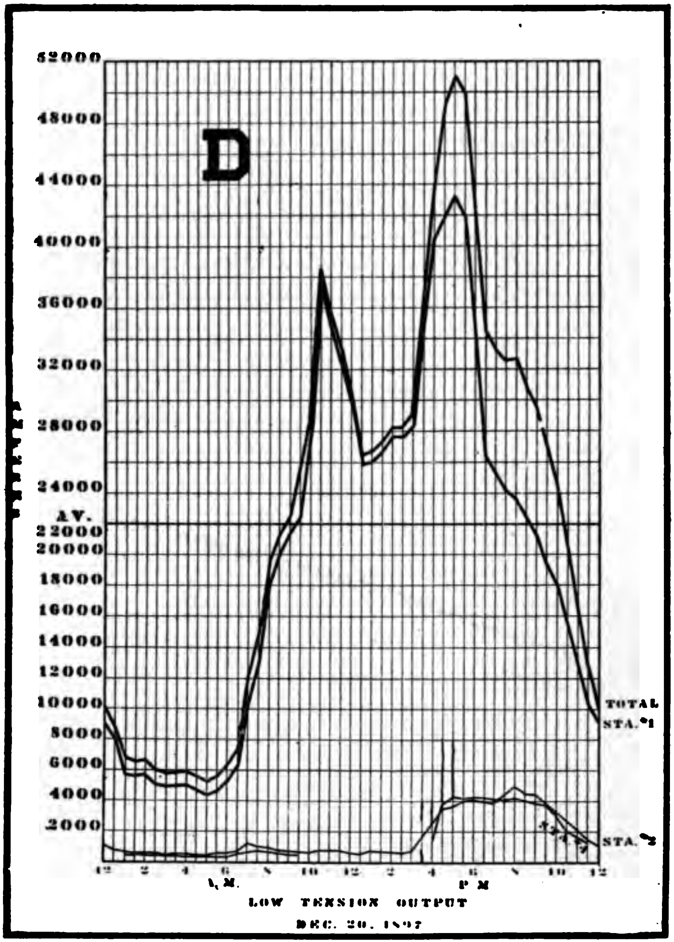
Storage batteries, when installed in central stations or centres of distribution, are usually connected to the main 'bus and allowed to float on the system, taking a charging current from the 'bus or discharging into the 'bus according to the load on the system, the generating units being worked at such loads as will insure the best efficiency of the entire system. Batteries are economically valuable in connection with the distribution of direct current in systems whose load curve has an average peak width of not more than two hours, since the investment required for storage batteries to carry the peak having an average width of less than two hours is less than the investment required in steam and electrical machinery to do the same work. The storage battery also has the same value that exists in the case of moving machinery as a reserve in meeting sudden increases of load, provided such increase of load does not continue for a sufficient period to wholly discharge the battery and insufficient time remains for recharging before the ordinary load peak of the system appears at the regularly appointed time. Such a condition is rarely, and I might say almost never, met with, although in rare instances we may approach this condition.

The steam and electrical machinery is rated by the horse power or kilowatt, and the duration of the load peak does not influence the value of the investment, since the machinery may be operated for the full twenty-four hours at its maximum capacity. The storage battery, however, is rated by the horse-power-hour or kilowatt-hour, and the investment is nearly directly proportional to the number of hours during which it discharges the maximum capacity; so that if we required the battery to be prepared to carry the full peak prolonged for seven or eight hours every day, the investment in battery would be enormous as compared with steam and electrical machinery to furnish the same kilowatt-hours' output. Illustrative



PROSPECTIVE CURVES
SHOWING BATTERY DISCHARGE
DIST. NO. 1

of such contingency, let me refer you to the load diagram marked "D," representing the load in the business district of Chicago, December 20th, 1897. This is a very extraordinary curve, illustrating the limitation of the storage battery and the possibility of



its having been rendered ineffective had the early morning peak extended to the arrival of the regular afternoon peak without affording sufficient time for recharging the battery.

The storage battery has a very distinct value, which is seldom recognized and employed to its full advantage, when located at the central distributing point of a system with feeders radiating to various points in the network. The battery may be provided with two or more end-cell switches, so arranged that they may be connected in multiple and feed into the main distributing-feeder 'bus, or they may connect also to one or more auxiliary 'bus-bars, with a different number of cells in series feeding into each 'bus, thus providing two or more potentials at the centre of distribution. It will be found that when only one pressure is maintained at the centre of distribution during the time of maximum load of a large district, the pressure at the ends of the short feeders will be somewhat higher than the standard, and they will be overloaded, and at the end of long feeders the pressure will be lower and the feeders underloaded, although the pressure variation at other times may be negligible. Under such conditions the storage battery becomes exceedingly valuable, for by arranging it to operate at two or more potentials, the long feeders may be connected during the time of maximum load to the auxiliary 'bus or 'busses and additional current forced over them, utilizing their full capacity and maintaining a uniform feeder-end pressure by means of an investment in end cells very slight as compared with the investment in additional feeders and mains required to accomplish the same result.

The direct-current distribution system is very much better adapted to electric-elevator work than the alternating-current distribution; and, so far as I am able to learn, there has not yet been developed a commercially-successful direct-coupled electric elevator capable of running at varying speeds and operated by alternating currents. The direct-connected electric elevator is a piece of apparatus that is of the greatest value to the central-station companies. since it is practically the key to the isolated-plant situation, and with its aid we are enabled in a larger percentage of instances to show to the owners of large mercantile establishments and buildings a decided saving in the purchasing from the central-station company of electricity for lighting, elevator and general power service as compared with the cost of operating an isolated plant, using hydraulic elevators. The immense advantage to the central-station companies in being able to supply commercially-successful electric-elevator service economically, may be realized when we consider that there is connected to the systems of the Edison companies in New York, Boston, Brooklyn and Chicago 15,000 horse-power capacity in direct-connected elevators, representing a gross income of approximately $375,000 annually. At the present time, alternating-current distributing systems confine us to the use of continuous-running motors belted or geared to the elevator pump or winding equipment; but such an arrangement is not fitted for first-class passenger service and is very uneconomical, and similar equipments using direct-current motors were in use ten years ago, and have long since become obsolete and have been entirely superseded by the direct-coupled electric elevator, which operates for approximately one-half the cost.

The use of low-tension, constant-potential arc lamps, connected in multiple to the distribution system, has made rapid strides during the past three years, and in New York, Brooklyn, Boston, Chicago and other cities, is fast superseding the use of series arc lamps wherever the low-tension mains operate, and the day is not far distant when series arc lamps will be employed only in the outlying districts where there is not sufficient business to warrant the extension of the low-tension distribution system. The competition effected by the Welsbach gas burner has done much to develop the constant-potential arc lamp, and it is safe to say that with incandescent lighting alone the central-station companies are rendered helpless against the improved gas burners; but a successful competitor has been found in the use of the three and one-half ampere, direct-current, inclosed arc lamp, and as proof of this we have only to compare the results of the central-station companies in the large cities, where these small arc lamps have been employed, with the conditions existing in the small towns, where alternating-current systems of distribution furnish incandescent lighting only. In the latter places, the Welsbach light is found to be in general use, and is affecting very seriously the earnings of these small central stations, owing to the lack of an alternating-current arc lamp, which would answer the purpose of the small ampere arc lamp used in connection with direct-current systems. Although very much has been done within the last year in the development of the large alternating-current arc lamp, it is still far from being in the state of perfection, and cannot be said to compare practically or economically with the constant-potential, direct-current, inclosed arc lamp.

The use of motor cycles and electric cabs employing storage batteries is becoming more popular every day, and in London and Paris they are used very largely; in Paris, an automobile club having been formed by people owning motor cycles. The central-station companies using direct current will undoubtedly find a profitable outlet for their product as the motor cycle becomes more popular, and by locating charging stations for the motor cycles along the central-station mains, the use of the motor cycle will become more extended.

When we consider the many practical advantages inherent to the direct-current system of distribution, which add so greatly to the commercial success of a central-station company, it would seem that the original investment required to establish the plant and system should not be the only question affecting the selection of the system to be adopted. It is universally conceded by all competent and unprejudiced engineers that the alternating-current system of distribution in a closely-settled district, which shall approach in commercial value the direct-current distribution system, shall be one that has for its basis an interconnected system of secondary mains, with transformers of large capacity, and high-pressure feeders from the central station to these transformers and generators in the station operated in parallel, as previously described. Therefore the cost of the distribution network in the case of the alternating-current system will not be less than that of the direct-current network; and the cost of transformers, high-pressure feeders and alternating-current dynamos, should be compared with the cost of low-tension feeders and low-tension dynamos of the same capacity, these forming the only points of comparison. The investment in each case depends merely upon the advantageous location of the central station in each individual city.

I have shown in the early portion of the paper that in a large distribution system such as exists in Chicago, seventy-five per cent of the total energy supplied to the system is delivered to the business portion of the city, covering an area of one square mile, the stations supplying this territory being three-fifths of a mile from its electrical centre. It is therefore self-evident that, since such a large portion of the energy supplied is so nearly adjacent to the desirable location of the central station, a direct-current distribution system should form the basis of the general system of the company.

It seems to the writer that the useful field of operation for alternating-current distribution system is not in large cities, but rather in the scattered suburban residence districts and small towns where commercial lighting, elevator service and general power distribution form an insignificant portion of the demand, and where the first cost of the direct-current installation would so far exceed that of the alternating-current system of distribution, with primary mains and large transformers for blocks of lighting, as to make the interest charges so great that the property would be rendered unremunerative.

The successful central-station company of the future will be, as outlined in my paper read before the Association of Edison Illuminating Companies at its last convention, the one combining intelligently the use of alternating and direct currents, employing direct current in the distribution systems in the thickly-settled business and residence districts of a city and alternating current for the distribution systems in the scattered residence districts and surrounding suburbs. The energy will be generated at one or two large condensing stations, located where water and fuel may be obtained at the minimum cost and the energy transmitted to the various sub-stations located at the electrical centres of the distribution systems. The choice of low-pressure direct current or high-pressure alternating current for the transmission to the sub-stations will depend upon their relative distance from the generating stations; rotary transformers or other forms of current rectifiers being employed in the sub-stations that supply the direct-current distribution networks when alternating currents are used for the transmission.

DISCUSSION

PROFESSOR FUJIOKA: *Mr. President and gentlemen*—Although I have the honor to be an honorary member of your association, I have very little opportunity to attend your conventions. I shall take great pleasure this morning in giving a short description of the plant and system that has been carried out under my direct supervision in Japan. I have no notes or papers with me at present to show you, so I will draw a rough map of Tokyo. We originally had five central stations. Station No. 1 was originally installed in 1888, entirely with the Edison three-wire system. Nos. 3, 4 and 5 were installed afterward, also on the Edison three-wire system. Before going further, I should like to say that there are some conditions peculiar to Japan; that is to say, the city of Tokyo has quite an extended area, occupying about one hundred square miles, and the buildings are scattered, and we have no high buildings, because of the danger from earthquakes. I saw the advantages of the Edison three-wire system of distribution, so we began to supply the more crowded parts of the city by means of the three-wire system. We subsequently found that it was necessary to supply current to more settled parts of the town, so we added single-phase alternating currents in most of the other stations. Since we have seen the advantages of the three-phase current transmission, we have decided to install one big power station near the river. All the former stations were worked with high-pressure, non-condensing engines—and I may state that coal in Japan, particularly in Tokyo, is very expensive, costing $5 to $6 a ton—so we found that it might be wiser to install a condensing station near the river, having triple-expansion engines. We installed ten triple-expansion engines on the condensing system, each engine directly coupled to low-speed generators; four of them single-phase and six of them three-phase generators. The three-phase generators were wound for 3,500 volts, whereas the single-phase were wound for 2,000 volts. We did not like to disturb the existing three-wire network in the crowded portion of the city; we wanted to keep the three-wire network as we have had it for about ten years. The way I did it was to place induction motors in No. 1 station, taking out all the engines and boilers and placing the induction motors in the same place where we had the engines, each motor driving two Edison bipolar dynamos; and we also installed a large storage battery in the old boiler room. I may state that the distance of No. 1 station from the new riverside generating station is about four miles, and the distance of No. 3 is about the same. In the same way, station No. 3 was changed to a motor-dynamo station, and in station No. 2 we have four induction motors, each 150 horse-power, directly connected to multiphase direct-current dynamos. No. 4 station was taken down altogether. In No. 5 station we took down all the old engines and dynamos, and placed three-phase transformers supplying current by the four-wire system of distribution. The more scattered portions are supplied by 2,000-volt, single-phase currents, raising the voltage at the necessary places to the required potential. In this way, we have succeeded in reducing a great deal of the expense in fuel and labor items. I cannot tell at present the exact proportion of the decrease, but we know that we have reduced the expense materially, and I shall be much pleased if this brief description shall convey to you some idea of what has been done in Japan.

THE PRESIDENT: The general subject of electrical distribution is now open for discussion. I would ask the various members who wish to talk on this subject to make their remarks as brief as possible, as it is now half-past twelve, and it is not desirable to continue the discussion more than an hour unless it is carried over until this afternoon.

MR. THAYER: I should like to ask Mr. Wagner two things: One is in regard to the design of these extremely large transformers. Does he regard it as advisable to obtain an extremely close regulation; that is to say, a regulation within one per cent; or is it better to have a slightly poorer regulation, and more iron loss? Also, how he does away with the difficulty of the excessive drop in the large conductors carrying the secondary currents proceeding from the large transformers?

MR. WAGNER: In regard to the first question, I mentioned in the paper that by making the transformer practically an integral part of the feeder we eliminate all the effects of transformer drop, just as we eliminate our feeder drop by regulating by the pressure wires from the feeder terminals, which become the secondary terminals of the transformer, so that we can sacrifice the regulation of the transformer to secure a very low iron loss; but I want to state further that a poorly-regulating transformer is very much better for use in a system where transformers are connected in multiple, provided the pressure for each transformer can be regulated independently. If transformers of very close regulation, one per cent or under, are connected in multiple with two or three hundred feet or more of mains in between, unless the resistance of the mains is extremely low, the transformers will not divide the load if it is not uniformly distributed along the main. In such a case, the transformer nearest the load will take practically all the load, so that for good distribution of load between the transformers, poor regulation is desirable, provided that regulation does not affect in general the regulation of the system; and it can be so modified that it will not do that, by making the potential of each transformer to be regulated independently by feeder regulators at the station, manually operated. The changes of load are slow enough for one attendant to take care of them.

MR. VAN TRUMP: I wish to ask, what is the objection to cutting the feeder transformer off the line automatically, and saving the underload losses during underload?

MR. WAGNER: The object is to make the underload losses so small that it will not be necessary to do that. That would complicate the operation of the system very considerably, both in the matter of attendance and in the use of switches and automatic devices, which are not, as a rule, to be depended upon. In the system described here, the highest efficiency is at the average load, so that if a transformer were cut out and its feeder were cut out, it would decrease the average efficiency rather than raise it, as it would increase the load on the other feeders, increasing the copper losses in the other feeders and transformers; and that increase in copper loss would be greater than the iron losses which you suspend temporarily. The object is to design a system to be most efficient at the average load. With large transformers, that can be successfully accomplished.

Mr. Robertson: What is the wattless-current loss?

Mr. Wagner: The wattless current is inappreciable. The volt amperes and the watts correspond so nearly in any alternating station at full load that the increase is almost inappreciable, even in the most poorly-designed station. The power factor is very high at maximum loads, and with a system of this kind the power factor should be practically 100 per cent at all times, except for alternating motors, which lower it slightly. The part of the load that comes on at the peak is principally incandescent lighting. The motor load is almost constant, and the arc-lighting load is much more nearly constant than the incandescent load. The wattless current is small compared with the other current, in any event, and it is found that large alternating-current generators can be operated with a considerable increase of current in the armature without materially increasing the temperature of the machine for short periods, as the greatest losses in the generator do not originate in the copper of the armature, and that can be very greatly overloaded without affecting the maximum temperature of the machine to any great extent.

Mr. Dow: I desire to discuss Mr. Wagner's paper in the light of information furnished in the paper itself. The points on which Mr. Wagner has based his curves are given on page 148. He states that the feeder loss in case number one is twenty-four per cent. That is an exceptionally high feeder loss. It is not radically different from the feeder loss in Mr. Ferguson's paper,—22.8 per cent—but that includes the tie-line losses from an Edison three-wire station located much farther from the maximum load than is customary. I think that, taking the average of Edison stations,—and this is assumed to be a representative three-wire, direct-current station—the feeder loss is more nearly twelve to fourteen per cent. I am familiar with one station where the feeder loss is under twelve per cent; others, fifteen per cent. As to the twenty-four per cent loss, I cannot think of any station—except possibly the Chicago station with the tie-line included—where the feeder loss would approximate that. A slight modification in the assumed feeder losses will completely change the relative positions of the two curves numbers one and two; it will place number one above number two throughout its entire length. I think, also, that twenty-four per cent loss will, in general, bring the cost of the three-wire feeder—particularly the cable feeder, which is now the standard—to not much more than the cost of alternating feeder plus transformer, which Mr. Wagner proposes to employ. A cable feeder for three-wire system capable of carrying 100 kilowatts can be bought and pulled in for something like ninety cents per running foot. That is cheap construction, but it is a fair figure to compare with the cost of a transformer that is proposed to be used in place of, and to avoid the great expense of, that feeder. A transformer for 100 kilowatts will cost from $1,000 to $1,200, and the initial advantage of the $1,000 in favor of the direct-current system will pay for a great deal of copper; and the permanency of the one investment as compared with the other is much in favor of the direct current.

Taking again the figure on page 148, the loss in mains is assumed to be two per cent in both cases. Now, I rather take exception to that, with the conditions of load that will prevail in such a station as the representative Edison station, viz., with a large motor load and very respectable arc-lamp load. Under these conditions, the fact, which Mr. Wagner has noted in his paper, that the drop in the alternating-current main or feeder is not proportional to the current (which he sets forth on page 139, as follows: "It would be quite perfect if the drop in alternating-current lines were proportional to the current, but it is not"), will certainly affect the amount of the investment as between mains for direct current and alternating current. To get the two-per-cent regulation in the mains will certainly involve considerably more investment if the supply is to be by the alternating current.

The questions as to arc lamps and motors are discussed by Mr. Ferguson, and the statements made in his paper can be applied directly to answering Mr. Wagner as to the quality of the two systems in these respects. I also wish to accent strongly Mr. Ferguson's statement that the electric elevator, which Mr. Wagner says is just now a difficult and unsettled problem for the alternating-current station, is of primary importance to central-station interests. If you are not able to give good elevator service, you will have to submit to the establishment of many isolated plants. It is a sure sequence that if a man has to keep an engineer on his premises, a steam boiler and a steam pump, for the purpose of running an hydraulic elevator, he will add a dynamo and an engine to supply his own light. On the other hand, if you can furnish him good elevator service, at a reasonable rate, the necessity for the engineer and for the high-pressure steam is eliminated; and in that very fact lies the possibility of blocking the establishment of isolated plants. In my case, to lose the elevator service would not be a serious matter so far as the elevator bills are concerned, but the incidental loss of a good deal of valuable lighting would be very serious indeed.

I should say that Mr. Wagner has shown in his paper what many of us want to know: that the alternating-current service can be wonderfully improved above its customary standard; that it can be brought up closer to the standard heretofore set by the direct-current stations; but that it is still an inferior service for the conditions that Mr. Wagner has defined as those of the "representative Edison three-wire central station." In the case of the densely-populated central district demanding the greater portion of the total output, the direct current is unquestionably the best. The less densely-populated outer sections might be supplied by the alternating system, or, as Mr. Ferguson has suggested, by an alternating transmission and direct-current distribution.

MR. WILMERDING: Referring to the question of the drop in the feeder on the number one curve in Mr. Wagner's paper, I would ask Mr. Ferguson if in his statement on page 140, in which he says that the drop on the trunk line was 12.4 per cent and to the customer's meter 22.8 per cent, he does not include all the losses; that is, include all the losses that might be made in the feeders themselves.

MR. FERGUSON: That includes the total volt loss from switchboard to the customers. It is the loss at the time of maximum load, and is not the average loss. The latter is given as 8.8, whereas the maximum loss is 22.8, and that includes the total losses from the station to the customer's meter, including all the trunk-line losses and the meter and main losses. As a partial answer to the question, and to help out Mr. Dow in what he was saying, I can furnish a curve that illustrates the point he brought out. I have a curve that represents a typical central station, such as has been referred to by Mr. Wagner in the general remarks in his paper, and represents the typical Edison station to which Mr Dow refers.

PROFESSOR GOLDSBOROUGH: In being permitted to make a few remarks on the papers presented, I should like to say, in connection with Mr. Wagner's reference to the sub-station transformer, that it seems to me that there is an opportunity offered to improve upon the low-load efficiency of the alternating-current plant which he has discussed. I notice that he has the alternating-current efficiency curve below the direct-current curve for values less than eight per cent.

This loss must be due to the inefficiency of the transformers, because the only difference between the two systems is in the transformers; the copper loss in the two systems being the same, the iron loss is therefore the important factor. He says that the iron loss is so small (as his figures indicate) that it is an inappreciable quantity. It seems to me, however, that if a system of sub-stations were devised and a number of transformers placed together, a set of feeders could be run from the central station to the sub-stations; and then, if some of the transformers could be cut out as the load diminished, there would be a gain in efficiency, as a certain number of the feeders would be used in common with a certain number of transformers, and the low-load iron loss would be less. With less core losses you would have improved efficiency at the lower loads. Improvement, I think, would be noticeable from about twenty-five per cent of the load down to very low loads; and it might be considerable, for the reason that as the load goes off, the power factors of the large transformers come into play. If you cut out some of the large transformers, and have a few of them fully loaded instead of many of them partially loaded, you will improve the power factor of the whole distributing system and thereby gain a great deal, because as you increase the power factor you reduce the volume of current required to supply a given amount of power. As to the means of cutting out and cutting in these transformers, it would be a matter of considerable expense to employ a man for that special purpose. But an improvement on this system can be devised. It might be a system of relays operated by means of small messenger wires. You could send out lines from the central station to the sub-stations, and adjust the transformers to the load by means of electro-magnetic devices, which would throw in or throw out at will switches connected in the primary circuits of the transformers. Such systems are in operation in England, to some extent, as well as on the Continent, and I believe they have been a great success. I see no reason why the low-load efficiency of an alternating-current station cannot be considerably improved in this way.

As to the matter of arc lights, I was pleased to hear that they are making a success in St. Louis. I remember that, some years ago, the Westinghouse company carried on an extensive series of experiments to reduce the humming of the alternating-current arc lamp. I imagine the humming is still a detriment to the old form of open series arc lamp. As to the inclosed arc lamps, we have made some experiments at Purdue, to determine the efficiency of all the types at present on the market, and we find that the efficiency varies very greatly in different lamps. The efficiency of the alternating-current lamps is much less, on the whole, than that of the direct-current lamps; the former average 3.9 watts per candle; the latter, about two watts per candle. If an open reflector above the arc lamp is used, it introduces a marked saving, and makes the comparison between the alternating-current and direct-current lamp much more favorable to the alternating-current lamp.

I was also much pleased to hear Mr. Wagner express himself so strongly in favor of the single-phase alternating current. The single-phase alternating current, to my mind, possesses the same features of simplicity that are possessed by the direct current. I believe that we shall ultimately get a good single-phase alternating-current motor. I have thought so for some time; but I do not think that there is one on the market at present that we can say is commercially successful in the broad sense of that term. The single-phase alternating-current system has many advantages over the multiphase system for lighting purposes, in view of the better regulations.

In connection with the arc light, it was said by some one a few moments ago that the alternating arc lamp had found a rival in the Welsbach burner. It was said that we do not supply the electric light so cheaply as the light can be supplied by means of the mantle. I think this is not altogether so. Then, again, the gas light is becoming unpopular; it is not at all suitable for interior lighting, and won't do at all for entertainments, as it makes everything look ghastly, whereas the arc lamp gives a very pleasant light. A strenuous effort was made in one of the cities in Indiana to supplant the alternating-current, inclosed-arc light by gas light. Matters went so far that the gas company put in the mantles free of charge and the people had a fair chance to test them. In a great many cases they were tried, and in many cases taken out again as unsatisfactory, and arc lights are being used.

MR. SCOVIL: On page 155 of Mr. Wagner's paper occurs this statement: "I might say that where lighting is a distinct feature, and first-class service is to be rendered from a large station, the three-phase system cannot be used successfully." If there is any technical gentleman that takes an opposite view on that question, I hope he will give us the benefit of his experience and judgment.

MR. RICE: I have visited the plants at Salt Lake City and Sacramento and spent several days with the designing engineers of both cities, and they both claim superior efficacy and elasticity for the three-phase system over the Edison three-wire, continuous-current system. They have the three-phase, four-wire distribution system in both places. The Salt Lake transmission line is thirteen miles in length and the Sacramento line is nearly twenty-one miles.

I wish to say that in the discussion of the two papers it seems to me that the features to be brought out in comparing the two systems as adapted to large cities, are:

1st. The continuous-current system is one that has been brought to a high state of development, whereas the alternating-current system is one that is just beginning to be developed. I think Mr. Ferguson's sample potential chart, taken from an alternating plant, is most unfortunate in that it does not represent alternating plants of the latest design. As it is now past discussion that alternators may be thrown in parallel in the same manner as the continuous-current generators, we can therefore secure as constant potential.

2d. The alternating-current motors have not been developed to the same extent, or applied as universally, as continuous-current motors, simply because the alternating-current motors have not lived long enough. In time, I expect to see alternating-current motors distributed as widely and as universally as the continuous-current motors. The same might be said of arc lamps. We have had arc lamps for a great many years on the continuous-current system, but only recently have they been developed and made acceptable on the alternating-current system.

MR. PILLSBURY: I wish to say a few words in regard to the alternating-current motor, having been identified for several years with their development, more especially of single-phase machines. The question has been raised by one gentleman as to their power factor, by another as to their practical success, and by several as to their adaptability for the direct driving of elevators. Single-phase alternating-current motors are now made equal, if not superior, to direct-current motors for general power distribution. The power factor in a well-designed machine may be considerably above ninety per cent—from fifty to 150 per cent—of its rated capacity, and above eighty per cent while the motor is developing twenty per cent of its rated output. For general power distribution these are superior to direct-current motors in point of care and attendance required, average efficiency, absence of wear, etc. They have not as yet been applied to the direct driving of elevators, but there is no reason why they cannot be adapted to this work as soon as a sufficient demand shall have arisen. The only problem met with in their application to this class of service is that of starting. There are two methods of doing this; one by splitting the phase, and another by introducing a commutator; either of these is entirely successful. The latter is the more efficient for general power distribution, and is undoubtedly to be preferred where an excessive starting current is objectionable because of its likelihood to produce a fluctuation in the pressure at seven and at one o'clock, when many motors are being started at once. It is, however, not well adapted to elevator work, because sparking cannot be altogether eliminated from an alternating-current commutator. While this spark is not objectionable where the machine is started only occasionally, it would be decidedly so in the case of an elevator starting many times a day. The other method, as at present developed, gives ample torque, but at a comparatively low efficiency and by the use of a large current. The efficiency of a direct-current motor, however, is also low in starting, and ofttimes the current consumed is excessive. I apprehend, however, that, inasmuch as not all the elevators have to be started at once, this is a matter of comparatively small importance to the central station. It may be confidently affirmed that single-phase alternating-current motors are now on the market that are superior to direct-current machines for general power distribution, and that in the near future they will be adapted to such special work as the direct driving of elevators with entire success.

Vice-President Stetson in the chair.

Mr. Insull: Gentlemen, I operate a company that is in no sense wedded to one system or another.

Within the last week I have shut down a three-wire Edison station and now operate that particular three-wire system with alternating converters. I should like within the next week to shut down an alternating system. With us it is simply a question of the most money we can possibly make out of a given investment. I think that if you will study Mr. Ferguson's paper you will find that he has not gone into this question merely from a theoretical point of view, but that his observations are based upon the actual results obtained in a year's operation of a large property. This property has been in existence some ten years. If you study Mr. Wagner's paper, you will find that he presents to you for use in our large cities, principally,—as his paper is based upon operations in a large city—a new scheme, which has not stood the test of time, and which cannot be set up in comparison with the low-tension system until a company using Mr. Wagner's plan has developed its business to a point where you can make a comparison of investment with investment, expenses with expenses and return with return. I know that most of you gentlemen here are alternating men, and that you look upon me as a low-tension man; but I would remind you that exactly what Mr. Wagner has stated this morning with relation to the advantage of an alternating, distributing system as against the present three-wire system, was stated for different reasons, of course, with relation to the alternating house-to-house system that you are now using as against the three-wire system some ten or twelve years ago. Now, what has been the test of time? The manufacturer used to tell us ten years ago that alternating-current generation, with house-to-house converter distribution, meant a very much lower investment cost to the parties providing the money. Exactly the contrary has proved to be the case in any large centres of population where there is much business. It has also been proved that in the smaller centres the losses are so great that some such scheme as that Mr. Wagner propounds is absolutely necessary if you are going to sell electricity in competition with other forms of artificial illumination. I do not know that I am competent, in fact, I do not care, to go into the slight differences that are shown by Mr. Wagner's theoretical percentages on one hand and Mr. Ferguson's absolute figures on the other hand, and the slight difference of economy that Mr. Wagner claimed. What I should like to know from Mr. Wagner is whether he has a statement of his generated output for a year and his delivered output for a year, and what is the difference between the two, and how closely they compare with the percentages as stated in his paper. I should like to know at the same time how he has obtained a record of his generated output. I tell you, gentlemen, that the Chicago Edison company cannot swear to any absolutely correct output at the present time, and the differences of efficiency claimed by Mr. Wagner might possibly disappear in the personal errors that might enter into the calculations. If the Chicago Edison company could profit by the adoption of Mr. Wagner's scheme (and I doubt whether Mr. Wagner would claim that), the only changes we should have to make would be in our feeder system, and those changes would depend on whether or not our insulation would stand the high voltage. Our distribution is a permanency; it has not changed from year to year. We have not been trying, first one translating device, then a new system of distribution, and then another translating device,—all of which pile up big interest cost; we have been working on the same lines; and I should like to ask Mr. Wagner whether or not if the city of St. Louis, in which he has done such good work with the alternating current, had started first of all in the central portion of the city with an Edison three-wire system, he would have any reason to change it to-day?

I think a little retrospective view of the industry might possibly help you in looking into the future. I think you might come to the conclusion—certainly you that are running large companies, you that have made a handsome return on the investment from the very first, who started originally on a scheme of distribution that has not varied since the introduction of the three-wire system—I think you might find that it would be better to continue that course wherever you can rather than to adopt something that is radically new, untried, and that has not had the test of time; untried, I mean, except for a comparatively short time. Our company, with the exception of two or three other companies represented in this room, sells more alternating current than any one here. The systems that we have are on a house-to-house plan, which, as you know, is not satisfactory, and the losses are enormous; and the difficulties of handling the proposition for the future are for the moment apparently insurmountable. The plants bear evidence of the fact that the engineering was of the poorest character, that the system as a whole was never properly thought out. I do not know to whom Mr. Wagner refers when he says: "The standpoints in general mark the difference between the manufacturer and the user, and we find these two systems developed in this way,—one almost entirely by the manufacturer, and the other by the combined efforts of the various users." I know that some systems bear apparent evidence that they were developed by the manufacturers for the purpose of selling large amounts of apparatus; as to which system was developed by the users, I am in doubt; probably Mr. Wagner can explain it.

Mr. Wagner made some facetious remarks about these "beams of copper." These beams of copper earn a return for my stockholders. As to whether you shall have beams of a certain size, is simply a question of interest cost, fuel cost, and other incidental costs under varying conditions. With fuel very low, an Edison man would naturally decrease the size of his beams; with fuel very high, he would naturally increase the size of his beams. It is a question of balancing the interest cost against the other portions of the cost, and the size is simply an incident in the matter.

Mr. Wagner referred to the use of storage batteries. I may say that I agree with him to some extent. He says in his paper that you may ask as to whether storage batteries have been proved to be a valuable adjunct to the central stations, cost and maintenance considered. I would ask him whether his proposed system of alternating distribution has yet been proved to be a more valuable adjunct to the central station as compared with the three-wire, low-tension system? So far as the Chicago Edison company is concerned, and the use of its storage battery, as the battery only went into use yesterday we are not in a position to say much about it at the present time. We are to some extent trying an experiment. It is true that it is an expensive one, but it is still an experiment. One of the electrical journals recently quoted me as having changed over from an opponent to an advocate of storage batteries. They were a little previous in making that statement; but I can say this, that one of the primary reasons for our deciding to use a storage battery was the difference in the investment costs between the battery and the generating apparatus and trunk line that would have had to take its place. Interest cost comes in in all these matters. It is a question of conditions.

Now, as to Mr. Wagner's closing claims. The first is—*Highest possible efficiency of distribution and operation.* I judge from that that Mr. Wagner means that the cost of distribution and operation will be lower in the alternating-current system than in the case of a three-wire system. My claim is that this has to be proved. It has not thus far been proved anywhere in the world, and it afforded me great pleasure in listening to Professor Fujioka to learn that the new civilization of the far East has about the same engineering ideas as one of the most advanced cities in the civilization of the West; if you will excuse the comparison.

The next claim is—*Best regulation.* You cannot have anything except perfect regulation. Our charts are at your disposal, gentlemen. If you have any doubt as to the chart shown you by Mr. Ferguson, as to whether it was selected, I think we have them for several years back, and I am prepared to stand on the matter of regulation by the record shown by our business and the record shown in connection with Mr. Wagner's scheme.

The next claim is—*Largest territory desired and readily supplied from one station.* There comes the question of investment; it is simply a question of conditions. The greatest claim is flexibility. If you can find anything more flexible than a system operated during the whole of the twenty-four hours, first from one station, then from two, then from three, carrying at the same time during the twenty-four hours current 13,000 feet from the point of generation with a loss almost impossible to figure out,—if you can find anything more flexible than that we shall be delighted to adopt it.

Another claim is—*The only system in which all classes of service can be supplied from one type of generator.* I take issue, and challenge him to show a plant in operation where that condition exists except in the case of the low-tension, direct, three-wire system. I have not seen it. I should like to know from Mr. Wagner whether it is just as easy to operate an alternating-current station with the dynamos in multiple as it is to operate a direct-current station, or whether it requires expert service to do that work and watch it to see that nothing gets out of whack during the twenty-four hours. I should like to see such a station if there is one. The question of investment is one that Mr. Wagner cannot overcome in most of the cities of the United States. That is where the shoe pinches. The investments have already been made. In any new system that you put into use you have to get a return on your existing investment and a return on your new investment, and provide enough money to wipe out, in the shape of depreciation, either the old investment or the new investment. You have to get that money from your customers, and that, of course, carries us back again to the early mistakes. I think it was Mr. Bowker, the vice-president of the Edison Illuminating Company of New York, who, when we first started to discuss this question of the use of alternating current in connection with the low-tension Edison station, pointed out the absolute permanency of the main investment in low-tension work, that is, the distribution system; and although Mr. Wagner may be correct in the claims he makes as to percentages of efficiency,—I am not competent to offer an opinion on that subject—I would warn you to go very carefully, certainly in the large cities, about adopting a scheme over one that has received the test of time. So far as widely-distributed areas are concerned, there is no doubt that the alternating current is of great advantage to us; but in big centres of distribution, I think that the experience of electrical engineers the world over has shown that the one system to use, and the one by which we can make money, is the Edison low-tension system.

Professor Fujioka: Permit me to make a few remarks. I had great pleasure in reading these papers. I agree with Mr. Ferguson's ideas at the end of his paper, when he says:

"The successful central-station company of the future will be, as outlined in my paper read before the Association of Edison Illuminating Companies at its last convention, the one combining intelligently the use of alternating and direct currents; employing direct current in the distribution systems in the thickly-settled business and residence districts of a city, and alternating current for the distribution systems in the scattered residence districts and surrounding suburbs. The energy will be generated at one or two large condensing stations located where water and fuel may be obtained at the minimum cost, and the energy transmitted to the various sub-stations located at the electrical centres of the distribution systems. The choice of low-pressure direct current or high-pressure alternating current for the transmission to the sub-stations will depend upon their relative distance from the generating stations; rotary transformers, or other forms of current rectifiers, being employed in the sub-stations that supply the direct-current distribution networks when alternating currents are used for the transmission."

As I said before, our station was built five years ago on this system that Mr. Ferguson advocates. Our largest station is for one-mile radius, and the motors are three-phase, with the motors and generators coupled together. But in some quarters, that are less crowded, where the areas do not exist to an extent beyond two blocks, I am using at present the three-phase, four-wire system, and, curiously enough, we are using Wagner transformers.

MR. AYER: The discussion resulting from papers like these, so far as it has gone, largely relates to the practice in large cities. The membership of the association, however, is not entirely made up of representatives of large cities, and the discussion of the papers should take a trend that would benefit the greatest number, and it seems to me that there is ample food in these two papers to give us some lessons that will apply to all.

In considering the demands of a large city, we are compelled to consider about all the conditions of distribution that obtain in electric lighting, as the outlying districts correspond to our country towns, and portions of the city with small business centers correspond to the smaller cities; and to provide for these requirements I think we can draw some lessons from the papers that have been read. One thing that I think has been pretty generally understood by the operators of alternating central stations is the necessity for getting rid of the house-to-house transformer, which means going to the three-wire distribution. It seems to me now, from this discussion, that it is the thing to go to; in other words, that method of distribution is best which affords an investment that does not depreciate and that leads up to some settled method for one detail of our plant.

Because of the patent situation, Edison stations were not installed in places where they would probably be very desirable. To-day that reason for not installing them does not exist, or will not in the near future. As you have to make additional expenditures in the future, enlarge the plant and broaden it out, it is a question how to do it; it is a question of multiphase generators, single-phase, and in many cases a question of whether it is worth while to go into the investment necessary to install a low-pressure generating system. It is easier to add the alternating-current system to the low-pressure; but it seems to me that we can take our medium cities to-day and develop our three-wire distribution, with an idea of getting back finally to the direct-current distribution.

The reasons, to me, are obvious. In isolated plants they are invariably using direct current. These people may and should become customers of the central stations to a great extent. If you expand your alternating-current system to the exclusion of direct current, you are absolutely prohibited from supplying these people with current for motors, except in a very expensive manner. The motor business is coming to be quite a factor, as you appreciate. The alternating-current motor, while not developed to its highest efficiency and not so well known, may have great possibilities; but it is not going to exceed the possibilities of the direct-current motor for power from central stations. The question of the flexibility of the current, while not so much a question to-day as it was five or ten years ago, is still very important. The point has been raised about hydraulic elevators in medium-sized cities cutting off desirable sources of revenue. Printing presses are very troublesome to the alternating-current motor. There are other special uses and demands; but we know this, in regard to the relative value of these investments: you have to make some experimental investments to-day in alternating-current motors; you have the question of insulation to contend with, and in all high-tension devices (as you get up in pressure you decrease the life of the devices) the investment is of a less permanent nature. The character of the service that you can get from the one or the other is varied. It is certain that you can get good regulation from the direct current. Mr. Ferguson, in showing the pressure charts, showed us one house-to-house distribution on the alternating current, another on the plan that is outlined by Mr. Wagner for the ideal alternating stations, and a third showing the direct-current Edison. These charts were the ones to be considered, as I understand, in comparing the two methods. It is easier to regulate the low-pressure system than the high; but the question is to get the thing that will bring you the greatest amount of business at all times, and that question is a pertinent one. The low-tension system does that to-day.

If the cost is not going to be excessive, it is the one to go to; the character of the investment is superior to anything that will deteriorate more rapidly. The distribution of power is a thing that comes slowly for a time with your alternating-current motors. You have your investment to-day in the single phase, and while we have the statement that a perfectly satisfactory single-phase motor is in the market, we know they are not in general use. Many of the members have experimented with them. There is no question but they will come and will be satisfactory; but they are not comparable with the direct-current motor to-day. Isolated plants, however, will invariably, in the future as they have done in the past, put in the direct current, and you will lose the possibility of a large amount of business if you extend your alternating system rather than to extend the system with direct current. It is practicable in many cases to put in three-wire distribution, and get ready for your next station apparatus to be direct-current.

The arc-lighting problem, to me, is one that is readily solved with the direct system, and for outlying districts and municipal lighting the constant direct-current series system should be used. There is no question in the mind of anyone that has ever attempted to compare the alternating current with the direct for street lighting from series or multiple arc lamps, as to which is superior. The very nature of the current makes it a certainty. You get the strongest rays where they are useful; no reflectors are necessary to carry this light down. Reflectors are unsatisfactory in streets, and will not keep clean. Without them you cannot get even fair service from alternating arc lamps. For municipal lighting, where you have to traverse wide areas, the series system is best adapted; and I think you can safely, in many cases, put up with the annoyance of having separate dynamos for taking care of your outlying districts rather than be hampered by the restrictions that govern the alternating-current arc lamp. The alternating-current arc lamp will not stand in competition with a series arc lamp, direct-current, as developed to-day. What it will be in the future, we do not know; and we would rather not spend our money on futures.

At the association meeting in St. Louis, in 1893, we had a series of papers on the alternating current, treated singly, two-phase, monocycle and three-phase, attempting to bring out the merits of the different kinds. To-day we are asked, "Which is the best?" The station manager gets up and would like to know why Mr. Wagner thinks there is only one method. It seems to me that there are no very decided opinions as to the value of the various alternating-current systems for the universal use to which central-station managers want to put them. At that meeting we tried to bring out, looking to the future,, the point as to what we had to do with. Should we have in the near future, or did we know of at that time, an alternating-current motor that could be relied on? Did they know of a single-phase alternating motor? The answer from all the members of the manufacturing companies producing alternating apparatus was that it was not probable that we should get a satisfactory and efficient single-phase alternating motor. The only dissenting opinion from that—by anyone representing the general manufacturers, and he only indirectly—was by Prof. George Forbes, of London, England. He stated that it was his pleasure to announce to the convention that during the then past year he found in several large manufacturing establishments in England single-phase motors working satisfactorily. He expected that in a year we should use them. That was in 1893, and tells us in a measure what is ahead of us in speculating upon what is possible.

A retrospective view is important, and I think Mr.

Insull struck the nail on the head in insisting on a very serious retrospective view of the two different systems; and I am inclined to think that the average central-station manager, if he could turn his station over to-day into the direct-current system, would find his nights more comfortable, and his days also; particularly during thunder-storms where there are overhead wires. In many cases a mixed system will be necessary to get the best net results. For transmission, alternating current will be used; but the direct-current must always prove most desirable for distribution. Where alternating current only is practicable,—and there are conditions where a central station should use it—it goes without saying that the method outlined, or substantially that, is the one that should be taken up wherever the conditions warrant it; but I want to express my conviction very firmly that the old system is the best one for general use in central stations.

THE PRESIDENT: I wish to know your pleasure, gentlemen; shall we continue this discussion, or adjourn to the afternoon session? It is now ten minutes to two o'clock. Mr. Wagner and Mr. Ferguson are yet to be heard from. If there is no objection, the meeting will stand adjourned until three o'clock.

Adjourned.

FOURTH SESSION

President Insull called the meeting to order at a uarter past three o'clock, and announced that the iscussion on methods of distribution, which was nterrupted by adjournment, would be resumed.

MR. FAKES: I desire to state that your remarks in regard to the use of meters, and that the central station not using them would sooner or later go into the hands of a receiver, struck me very forcibly, as this is our position to-day; nevertheless, we do not blame the alternating system for it. In the first place, we installed the National incandescent some nine years ago; it proved to be a very expensive experiment. Later on we installed the Royal, which has proved to be not so expensive. Our station is small, having 1,200 lights installed. I think the peak of our load is some forty-seven amperes. We have a very few meters, of the different standard makes, but our principal rates are on the flat-rate system. The principal point that I wish to bring out is this:

Our station is operated all night with forty-two Western Electric arc lights running all night. We run seventy-nine arc lights until twelve o'clock, and then we run the forty-two city lights until morning. We also run the incandescent lights all night. About seventy-five of these run all night, or from midnight until morning. We use two tons of coal for an average run of eleven and one-half hours on our city arc circuit and thirteen and one-half hours for the incandescent circuit. We run from midnight until morning on three-fourths of a ton of coal. We have no station meter to tell us what the output is, but we know we are operating at a very low cost, so far as our fuel consumption is concerned.

So far as getting money into the treasury is concerned, we are operating at very low expense from midnight until morning, so our system must have good regulation, running on the alternating system, because if there is so much loss in the transformer system, why would it not cost more to run from midnight until morning, with seventy-five all-night lamps? That, I think, is a point that is valuable. I want to say that, although we are in the hands of a receiver, we are making some money.

MR. DAVIS: I should like to get the experience of any station that is now using or installing alternating, inclosed arc lamps in competition with the Edison system, and to know whether they can get as much per kilowatt for current used in such inclosed arc lamps as the Edison company in the same city charges for current used in direct-current, inclosed arc lamps.

MR. STETSON: I will not answer that particular question, because we are not furnishing that particular line of light; but I will say that I represent a company that has both systems. We are running the Edison and the alternating systems, and I am sure I do not know which one we could spare; we want them both; I think it is a very good combination. We extend our light into a neighboring community, running four or five miles. We certainly could not do that on the Edison system; and whether it is a matter of the greatest economy or the difference in economy, it is the getting your money after you have a station established. The cost of a few more lights is generally the cost of the coal; that is, your interest and labor is a fixed amount; and if you can add outlying districts by any system, it seems to me that it is a good idea to be able to use that system. We find that it helps us in our income to take on this load of a neighboring town, which would be entirely out of our reach with any other system than the alternating on account of the small service required and the prohibitory factor of supplying that amount with an extensive output of copper; so that I do not know that a man makes a mistake if he has both.

I understand perfectly well that if a man were establishing a plant for a new enterprise, then the serious question would come in as to what he should do. But most of the gentlemen here have inherited their plants as they are; their predecessors handed them down to them, and there are not many of them whose stockholders will allow them to throw them away; they must get along with what they have. I suppose that the majority of this convention is made up of what these emperors of the situation, such as do business in New York or Chicago, would call small installations; and the conditions in each installation and each community have to be met.

I was pleased with the remark of our president this morning when he recommended that the alternating interests should establish themselves in some large community and prove their statements. If he will give us a record of any large community, like New York, Chicago or Boston, where the Edison company has not already obtained all there is in it, I presume the other people will be glad to go there and put up a plant.

But my advice to those people is to keep out of those positions if the other fellow is there. There is no question but that the simplicity and the fixed conditions of the Edison system, where the service is compact enough, make it a beautifully simple and elastic system. Whether it would be possible in the future to meet the advance of the alternating system, and to distribute the current over larger areas by raising the current, making the 220-volt lamp a success, and carrying out on the three-wire system 200 volts and reducing your wire expense, at the same time increasing your field, I do not know. It may be possible. That would be a counteracting movement on the part of the Edison people. I think it is fairly established that it is possible to make a practicable lamp taking this high voltage. That would be in favor of the present Edison establishments. What I should like to impress more particularly upon those people that are in the same line as myself, is the great advantage of doing away with the small converters. We are selling some wagon-loads of these converters for a little less than the price of the iron. If there is any point in your districts where you can make larger installations in the way of converters, using them as the distribution in the three-wire system, you will find that there will be a great economy in the cost of your service. The larger converters are more economical.

There is another thing—whether it is not policy for you to tell a man that wants a five-light converter and one light on his cigar counter that you do not care about taking that kind of service. If he is not going to be a profitable customer, it is better to let him go than to get into the hands of a receiver. That name indicates what it is spelled for; they take the whole thing when they get in; they leave very little after them. I desire to impress on those using the alternating system a careful study of their system and position, and the changing from small converters, so far as possible, to the larger and to the distribution of their current through the three-wire system. That would probably necessitate your throwing away your fifty-two-volt lamps and using 110, or about that. I have an idea that the lamp breakage is somewhat larger on high voltage than on smaller; at the same time, the cost would be in favor of installing the larger units as far as possible.

I think there is a great deal of virtue in the combination of the systems. I presume there are a great many positions where the very best results could be obtained from such a combination; I do not know how they could be got in any other way; how you could take a large area of suburban district and make a distribution; with the Edison system I cannot see any other way, where you have a compact unit and the possibility of conserving (or serving) the central section, in which you could do better than to use the Edison system; so it seems to me that it comes to a point where we should have to hunt for the best thing in both, and under a good many conditions it is practicable. The conditions that prevail in the larger cities have little analogy to the systems we are working with. There is no question but that the management of these larger cities and communities is entirely correct; and I think that the very strongest argument that has been presented here to-day was what the president said; and the fact, knowing as we do his fine financial instincts, that it would not take him long to tumble from the Edison to the alternating if there were a dollar in it, is a strong point in favor of the system he advocates.

MR. VAN TRUMP: Mr. Ferguson speaks of the maximum pressure being 149 volts, and the average pressure of all stations 126.2 volts. From that he figures that his average efficiency of distribution is 91.2. It seems to me that with the 149 volts as a maximum pressure the watts loss at the time of maximum load would form a very much larger proportion of the loss on an Edison station than the mean volts would indicate. I think that the watts loss would be much larger than 8.8 per cent.

MR. FERGUSON: The efficiency of distribution is arrived at by taking the ratio between the pressure delivered at the customer's meter and the average station pressure for the year, which is 115 divided by 126.2 volts. The maximum station pressure at the time of maximum load has nothing to do with the case; that is 149 volts, and is maintained for a short period of time. The true calculation is obtained by considering the average station pressure of 126.2 volts as I have given it, which is obtained by dividing the whole yearly watt-hours by the average amperes for the year.

MR. DE CAMP: What is the natural drop in the lines under normal conditions?

MR. FERGUSON: The average drop is 11.2 volts, or 8.8 per cent.

MR. DE CAMP: That is the whole year. What drop did you have between your switchboard and terminal?

MR. FERGUSON: The original distribution had a maximum drop of ten per cent; the average drop was about three and one-third per cent. The maximum drop from the centre of the distribution to the feeder ends is now ten per cent, and the average drop is 2.7 per cent for the year; showing an efficiency of distribution of 97.3 per cent. That would correspond to the average Edison central station where the station is located in the centre of the business district.

Vice-President Stetson in the chair.

THE PRESIDENT: I think a short explanation as to our conditions will make this matter plainer. We had a station in the centre of the city, in Adams street, where our present centre of distribution is. We moved 3,400 feet from there, in order to have the river on one side of the station and the railway tracks on the other side of us, to enable us to get free water for condensing and to get coal at the minimum price. It is simply a question of balancing fuel and labor cost against interest cost. The reason of the excessive drop here is because of the peculiar local conditions. We can buy coal very cheap, and we do not have to cart it, as we are on the railway track. On the other side of us we get Chicago River water for condensing and feed-water purposes for nothing except the pumping, so that our excessive drop is a question of spending money to save money. The cost of the energy lost owing to the drop is less than would be the amount of interest on additional investment in copper.

MR. HUBLEY: Our station has about 2,000-kilowatt capacity on the alternating system; 870-kilowatt capacity on the arc system, and 1,000-kilowatt capacity power service. It seems to me that the main question of central-station operation is the one of converter losses; that is, iron-core losses. We find that we have about fifty per cent loss on alternating-current station operation, due to constant losses in converters. Three years ago the losses were about seventy per cent. We have made an improvement by using better converters of larger sizes; and at present our converters are of latest improved types of prominent manufacturers, arranged, so far as commercially practicable, according to local conditions governing, to give the best possible results. I have here some data of tests of converters, taken from four types of different manufacture, and from them I find that the iron losses on a good converter will run from four per cent with small sizes to possibly one per cent on larger sizes. These, we have found in practice, will run very much higher, as the initial conditions cannot be maintained, owing to "fatigue" or increase of iron losses. I will quote an instance in the case of a ten-light converter.

The first test showed core loss twenty-seven watts, or five and four-tenths per cent; and second test, after one year's service, showed sixty-five watts, or thirteen per cent. We have converters that have as high as twelve to sixteen-per-cent losses in the smaller sizes, from 500 to 2,000-watts capacity; in extreme cases we have had as high as twenty-eight per cent loss. These losses increase constantly, due to "ageing" or "fatigue" of iron, and from practical experience we find no regularity or proportional percentage of increase due to this cause; and in no case can claims of manufacturers be substantiated or maintained. We have had, in our experience of the past few years, (during which time we have completely overhauled our transformer system by replacing same with modern and improved apparatus and arranging according to most advanced ideas), converters that would pass our adopted specifications as being very good converters, and within six months' service would increase from 200 to 300 per cent over initial test, which would make them more profitable in the scrap pile than in service. Of the different sizes of converters, we consider a converter that will run anything under eight per cent on a ten-light capacity (500 watts) to one and one-half per cent on a 500-light capacity (25,000 watts) as being a good converter for service. We find in practice that the losses will average as high as twenty per cent on small sizes. Converters in service, which under actual test had four-per-cent iron-core losses, and after a year and a half of service had thirteen-per-cent. In another case, a twenty-light converter, which had six-per-cent iron-core losses at the beginning, had sixteen-per-cent at the end of two years' service. The all-important question with the alternating system is the fact that manufacturers have not been able as yet to manufacture converters without these losses, or to maintain such losses within reasonable limits. I should like to hear the experience of other members who have investigated this question.

MR. DE CAMP: I wish to ask a question. I remember very distinctly that in one of our meetings, as far back as '97 or '98, it was said that the only transformer to use was one of a large size—with reference more particularly to house lighting. It was said that the only way to do was to put in a converter large enough for a whole block. At the next meeting the whole thing was changed, and, as I understood it in the discussion at the time, that was due to the large loss in the large converter when it had a small or no load, which is very apt to occur during a large portion of the twenty-four hours in house lighting; and they went, therefore, to small converters, which were more nearly the capacity of the individual installations. Then I heard again—at least I so understood the situation—that that would not do; that the aggregation of the losses in the small converter was much larger than that which existed in the larger converter. I want to know which is the best to use; a large number of small converters, or one large converter for a number of installations.

MR. THAYER: I have been at work for the last three years in remodeling our transformer distributions, and perhaps a short account of what we have done and the results we have arrived at may clear up this question somewhat. When I first took charge of our station there was a large fire, which burned out most of the original stock of transformers, Type E, General Electric, twenty- to forty-light sizes. They had an iron loss of 150 to 200 watts each. We began first by putting in a few large transformers, in the neighborhood of 100 lights each. After we finally got started we decided to make our distribution on the lines of the Edison three-wire system. To that end, we threw out all the fifty-two-volt lamps and made the 110-volt lamp our standard. We threw out most of the old type of transformers. Four of the transformers reduced the iron losses down a little over one ampere. At present we are using 3.1 and 3.3-watt lamps in our downtown district. We have most of our lamps wired on the three-wire system. Our transformers downtown are largely connected into the three-wire network. Whereever the residence lighting is at all heavy near the business districts, we have put in a transformer of from 100 to 150-light capacity, and they run tie-wires downtown. On week days the lighting load is rather lighter than on Sunday nights. It is heavier week-day nights downtown. Sunday night the conditions are reversed; the churches are on, and we have heavier lighting in our residence sections. That equalizes the drop, so that now we have a variation along our mains of about two per cent. We have been unable to do much with it in the outlying districts. In all cases, where possible, where there are three or four houses, we put in a fifty or sixty-light transformer and run it 110 volts. On the house-to-house distribution, wherever it could not be avoided, we put in 112-volt lamps. Our regulation was for four-fifths of our business from 110 to 112 volts, and on the other fifth, which is a small proportion, our voltage would run from 114 to 116. In that way we got our iron losses down to eight per cent of the ordinary maximum load. In short, we have simply adopted the Edison system of distribution, modified to fit alternating-current conditions; and we have found that there is no question as to the advisability of using large transformers, both in cutting down the iron losses and improving the regulation of the plant.

Mr. Chandler: I represent a station that is now running three systems. We inherited a regular low-tension, three-wire system. We found after a little, as the business increased, that we were running our interest charges up in copper to the extent of no profit. We then installed an alternating machine—monocycle, although we are running it simply as an alternator—and put in district transformers, 5,000-watt transformers taking in a section of residence distribution, and running the primaries to that and taking the regular three-wire system we have always had in use right around that. We have operated that with great success and satisfaction. We tap in on the Edison three-wire system and run a 1,000-volt current to the transformer, and the regular three-wire system from that. In some cases we have a system that we can switch from the alternating to the direct current as our needs seem to suggest. Then, through the centre of the town we still operate the Edison low-tension, three-wire system of 110 volts. We have the three-wire Edison system, two ninety-volt lines. It was simply our local conditions that made us experiment with this, but we find it a complete success. The section that is on the 220-volt lamp system is as well and economically lighted, and gives as good satisfaction, as any section that we have. It seems to me that the distribution by the large transformers on the Edison system to outlying districts, which cannot be economically reached with the Edison low-tension, can be reached with the alternating system in that way and have the advantages and elasticity of the Edison system. Local conditions make it advisable to use 500-volt circuit or the 220-volt lamps, and there is no question but that it can be economically done so far as the wire cost is concerned; and it has been a very satisfactory experiment with us, and filled in where the low tension would not. The local conditions would perhaps determine which is the more advisable to use. All three of the systems will come in, and come in profitably. I have no doubt that the large transformers are the most economical and elastic, and by putting in the district transformers of the size we use for our circumstances—which suits us better than any other size—we have a system that is elastic in every shape.

MR. SMITH: Mr. Wagner referred to the importance of running pressure wires from the centres of distribution to the station. I am about to run pressure wires in my plant, and should be pleased to know more about them.

MR. WALBANK: I have listened with a great deal of pleasure to the papers read this morning on these topics. There is one point, however, in connection with Mr. Wagner's paper, that I do not agree with. He says that the three-phase system is not adaptable to lighting houses.

I may say that we are installing at the present moment a three-phase plant of considerable size; a portion of it has already been in operation for six or eight months. Previously to that we had a single-phase plant with a capacity of between 4,000 and 5,000 lights. The present installation has reached 30,000 lights on the three-phase system. We run light and power, and have no difficulty in regulation. We have as yet no regulators on our circuits, depending entirely upon the regulation we can get from the rheostats. Eventually, we shall put on induction regulators.

We have a direct-current plant in the city of Montreal that will be driven by water by synchronous motors, and which will take care of elevators and motors already installed.

The principal objection to the alternating system is the price manufacturers charge us for motors. The public would prefer an induction motor but for the price; in fact, where we rent motors, the induction motor is preferred to the straight-current motor every time.

We are also running about 300 series arc lamps and about seventy-five incandescent arc lamps. I should therefore like to know from Mr. Wagner why the three-phase system is not adapted to lighting and power.

MR. CARNES: I know very little about the scientific end of this business. We run 500-volt arc and single-phase alternating. The discussion here rather makes a man doubt whether he will be able to live and be financially able to attend the next convention. We have not a very large station; about 600 arc lamps, about 500 motors of various sizes, about 35,000 alternating lamps, a number of inclosed arc lamps and about twenty-five single-phase alternating shunt motors. I must say that, although we are not up in all these modern improvements, we are very well satisfied; we declared a 100-per-cent stock dividend, and I guess nobody wants to turn loose their stock even now. We are going to wait until you demonstrate fully whether you have anything better.

THE PRESIDENT: We will now close the discussion on this subject by having some remarks from Mr. Wagner and Mr. Ferguson. As Mr. Wagner is a visitor to Chicago, we will give him the preference, and will call upon Mr. Ferguson to speak first.

MR. FERGUSON: There has been a great deal said here regarding the efficiency of distribution. Mr. Dow talked on that subject this morning, and I think that it is only fair for me to say, in the interest of the various Edison central stations that are running throughout the country, that the figures which I gave in my paper do not fairly represent the average Edison central station, but are really less favorable than might be shown by the average Edison station, considering the question of efficiency alone. I have, therefore, had a curve made hurriedly that will show you the real condition of the Edison central stations of the United States as compared with the curve that Mr. Wagner has presented for his station in St. Louis; and I would state that the general conditions of distribution represented by the curves shown by Mr. Wagner and those shown by the curve I now present to you are the same; in other words, the curve number two in Mr. Wagner's paper represents central stations that are located practically in the business centre of the city; and the curve that I now show to you represents the efficiency of distribution of the Edison central stations located at the electrical centre. You will see from this that the Edison central stations, such as they have in Detroit, and the older stations in Boston, and the original Adams street station of the Chicago Edison system, and plants of similar nature,—have a curve that at all times shows a higher efficiency than that of the best alternating-current station that has been presented. To my mind, the question of efficiency in percentages does not mean a great deal, for the reason that we have found it advantageous in Chicago to abandon the central station that gave that high efficiency curve and to build another central station three-fifths of a mile away to take its place. The new system of distribution will not give so good a curve as the one shown on the chart; neither will it give so good a curve as Mr. Wagner claims for his central station. But, despite that, the cost of producing a unit of electricity in the new station, with the poor efficiency of distribution, is infinitely less than it was at the central station that gave a higher curve of efficiency. Therefore, the real thing is not the curve of efficiency, but the actual cost of the production of the unit of electricity. In other words, I would say that it would be much better in the alternating stations that have been proposed to us that they be moved to a place where they can get water and coal at a reasonable price, and then transmit their energy to the central station, than to have the central station located as inferred from the paper.

I would call your attention to the fact that in the paper I have presented, in which I gave the losses in distribution, on page 169, you will find there two stations, numbers two and four, the first one of which has a high average station voltage of 119. That means an efficiency in the first case of

96.6 and in the second of 95.8; both of which are better than we get by the best alternating-current station. Notwithstanding these efficiencies, we have found it advantageous to abandon these central stations and generating plants, and to transmit our energy from the downtown station, even with quite an additional loss in conversion. We do this, in the first place, because the cost of apparatus at the last station is lower, and a great deal of labor is saved in the cost of production in the outlying stations, which give the high curves of efficiency.

The statement is made on page 175 of Mr. Wagner's paper: "We can even secure better general regulation than with the direct-current system, as we have a better form of feeder regulation and have eliminated the effects of the transformer drop." It seems to me that this is rather a broad statement in view of the fact that they have no pressure charts to show what the regulation is, and, further, in view of the fact that I have presented to the convention a pressure chart of a direct-current system which shows an average deviation from the mean pressure of less than one volt. It is almost impossible to get a better regulation than that. If you get a regulation within one volt, that is as good as you would ask for; and I doubt very much if any central-station system can be devised that would give better regulation than that, especially if any sort of feeder regulator is employed. My chart is taken from a system that employs no feeder regulators; it is self-regulating, with forty-two feeders radiating from a centre of distribution. There are no feeder regulators, and we require none. We can still present to you the chart as I showed it this morning. You can appreciate, if you have feeder regulators, that they require manipulation; and it is doubtful if you can obtain a chart that will be any better than the one that has been presented.

In regard to the alternating chart that I presented, there was one gentleman that took exception to that. I did not present it as representing the alternating-current system as outlined in Mr. Wagner's paper and representing my own as being the ideal one, but rather to show what is being done to-day and what has been done in the past in the average alternating-current station. I should like to see a chart from such a central station as Mr. Wagner described, and I am sorry he is not able to present such a chart, because I think it would be very instructive. Mr. Rice, I think, rather inferred from my paper that I thought the alternating machines could not be operated in parallel. We all know that it is being done in certain places. I simply wanted to demonstrate that if the alternating-current companies propose to have pressure regulation equal to that of the direct-current companies, they must operate in parallel; and until that is universally done, the alternating-current companies cannot hope to have the same regulation as is found in direct-current systems.

I think that the statements made by Mr. Wagner in regard to the amount of copper required, are somewhat misleading. When you consider the cost of copper in such an alternating-current system as has been described, together with the transformers for such systems, and the cost of copper in the direct-current system, the difference is slight in comparison with the total investment. I would also point out the fact that the cost of copper, of which such a strong point has been made, is really not so important after all, because the value of the copper is only about twenty per cent of the underground equipment;

so that even if you did make a material saving in copper, the total percentage on the total investment would be relatively very small.

I think I covered the question of meters pretty well in my paper; and I think it would be well for us to hear Mr. Wagner as to about the amount of power business he is doing with the single-phase system. In comparing the two systems, it is only right that the amount of power business that has been done in the direct and alternating-current systems should be stated, so that we may see the value of one system over the other in this respect.

In regard to the question of alternating-current series arc lamps, it should be understood that these lamps are not used for commercial lighting with the system as proposed by Mr. Wagner, but for street lighting, and I think it would be well for us to hear from Mr. Wagner the reasons why he does not use them for commercial lighting. The figures that have been given by me on the question of efficiency were taken from the records of the company for actual operation for the period of a year. These figures are all very carefully kept, and are to be relied upon. There is no speculation whatever in the figures that I have given, as they were taken from the actual statistics of the company; and of course we do not know about the figures on the alternating side, as the system outlined is not fully developed and it is possible that the figures are more or less speculative. It is a question whether or not it is fair at the present time to compare the two systems, one of which has been in use for a long time, the figures relating to which are reliable, and the other having been recently put into practice and the figures relating to it being in the embryonic state.

MR. WAGNER: Mr. Dow criticised the figures given for feeder drop in the curves showing the distribution efficiency of representative Edison stations. The figures were intended to approximate the conditions existing here in Chicago, and, as Mr. Ferguson has shown by his curves, the efficiency that I gave was higher than he actually finds. Mr. Dow thought it unfair to consider the Chicago system as representative. I was comparing it with a system that was being put in operation over a territory still more extended than that in Chicago, and in comparing the two systems it was advisable to approximate as nearly as possible two systems under nearly equal conditions, and the Chicago Edison company's efficiency was therefore considered the fairest point of view. I appreciate that there are many Edison stations in which the losses are much less, but the area over which they distribute is very much less; and by limiting the area, or by placing the station in the most central part of the district to be lighted, it is evident that the loss can be reduced to any degree desired. Considered from the most economical standpoint, the cost of conductors, the cost of real estate and the advantages of a location usually some distance from the centre of distribution, where facilities can be found for condensing and for getting coal cheaply, must all be taken into account; and while it is possible to reduce the distribution losses, as I said, to almost any extent, it is not, as a rule, economical to do so, as it necessitates a location that is not in itself economical for station operation.

Mr. Dow asked about the additional resistance in the mains where alternating current is used. That has been the subject of discussion from time to time, and also of calculation. All the tables that have been used show this increase in resistance, but they have only taken into account the cables themselves, and not the load on the circuit in connection with the cable loss, or the power factor of the load. Where these are taken into consideration, and the conductors placed as near as possible together and under one lead sheath with conductors as large as 300,000 circular mils,—which are as large as are generally used for distributing mains—the difference between the alternating current and the direct current is inappreciable. In numerous tests on conductors of that size, I have found that the difference in drop with a given current, with a power factor of 100 per cent, is about one per cent, or the actual drop is increased one per cent with the alternating current. With a power factor as low as seventy per cent, which is lower than any combination of power and light would be on such a system, it is increased to three per cent additionally; or two per cent drop with the direct current would be increased to 2.3 per cent. The additional cost for alternating mains on the three-wire system would therefore be practically nothing. The figures I gave on the efficiency of alternating inclosed arc lamps, comparing the watts consumed for a given amount of light with the alternating and direct current, are correct. They are made from actual experiment, and I can also say that the alternating-current inclosed arcs that we have in use are every bit as satisfactory as any direct-current inclosed arcs that I have seen.

MR. CARNES: Do you use them commercially?

MR. WAGNER: We have about one hundred in use commercially. In two months we have changed two lamps out of that hundred. The light is fully as good as that of the direct-current. It is not the standard alternating inclosed arc; it is made especially for a larger amount of current, and takes seven and one-half amperes and 110 volts, or 550 actual watts, in circuit. In addition to these lamps, we have 3,500 alternating arcs for street lighting and commercial lighting, and they are giving satisfaction. The open alternating lamps for commercial use are operated in connection with generator armatures especially designed to give a smooth and even wave of current, and there is less noise than in any place where I have seen arc lamps in operation. That matter was carefully considered in the designing of the generators. The inclosed alternating arcs are practically noiseless; we might have three in this room, and no one would notice the noise, with sixty cycles and the special form of armature referred to.

Mr. Dow also spoke of the increasing use of electric elevators with motors directly connected to the drum mechanism. I said in my paper that this is the only service that we are not able to render with alternating-current motors. I have, however, in the last few days, since preparing the paper, heard of one installation of six or eight elevators using two-phase alternating-current motors, which were controlled from the elevator in about the same way as direct-current elevators and directly connected to the driving mechanism, and were in satisfactory operation. It is well known that alternating motors can be regulated and the torque increased at slow speeds by means of suitable resistances. It seems only a question of a short time when this work will be accomplished satisfactorily by alternating-current, two-phase motors. Single-phase motors have not been tried for that, but a single-phase motor can be controlled in speed in exactly the same way, with a few modifications, that a two- or three-phase motor can be controlled, and I have no doubt that before a year has passed single-phase motors up to twenty-five horse power—which is as large as is necessary to run elevators—will be used for that purpose.

Some mention was made of the inferiority of the alternating-current motors for general service, but I think that was ill-advised. The alternating motors are undoubtedly superior in many points to the direct-current motors, as they have less complication of parts and need far less attendance. The efficiency is fully as good as that of any shunt motor. Mr. Dow referred to distribution over limited districts from the Edison stations. I want it understood that I do not favor the use of the alternating current in every location and for every application. There are times and places to use the alternating current. Where the distribution is over very small areas, even with the system I have described, for short distances the transformer cost would become a large factor of the cost of the feeder, and would probably, for a distance of less than half a mile, exceed the cost of the direct-current feeder. In that case, the direct-current feeder is the thing to use, unless the station also furnishes a large amount of current at a great distance, when the use of the several systems would be inadvisable.

Professor Goldsborough spoke of the use of sub-stations, and cutting off the transformers at times of light load. That should be done in small sub-stations; but in a system where the distribution efficiency is already slightly over ninety-six per cent on the average load,—and that is all we have considered—it would seem inadvisable to go to any expense to provide sub-stations, or devices for cutting in and cutting out transformers at sub-stations, to increase the efficiency. The cost of interest on the apparatus involved would decrease the ultimate average efficiency; and, more than that, the cost of sub-feeders from the sub-stations would again increase the first cost of installation and it would not be economical to have a large number of sub-stations; whereas, if the transformers are used continually in circuit they can be put in any location desired. The iron losses can be reduced to so very small an amount that further refinement seems unnecessary. He also spoke of the power factor with these transformers at light loads. The power factor due to the transformer iron losses in the system referred to could never, with the smallest load you could possibly have in actual service on the transformer, be less than 99.9 per cent, because the iron losses are so extremely small. They are .23 of one per cent of the capacity of the transformer. The inductance factor in that one per cent is practically negligible. Then, the use of sub-stations complicates the system; simplicity, without great cost of operation, merits very great consideration.

We operate the series open-arc lamps at fifty volts with cheap American carbons, and they do hum and make a good deal of noise; but they are only used for street lighting. We use no series alternating lamps for commercial lighting, even outside of stores, and we do not use them with the underground distribution. For commercial lighting, we find it more economical to use low-potential arc lamps, operated directly from the incandescent system, than to use a separate system with series arcs. Then, again, the use of the meter for arc lamps is coming into general practice, the same as for incandescent lamps, and, of course, the use of a meter is out of the question with series arc lamps. All central-station men agree that the series arc lamp for commercial lighting will soon be a thing of the past.

Single-phase motors have been pulled to pieces considerably here, but I can say that we have in use over one hundred horse power of these motors, the sizes ranging from one-horse-power to fifteen-horse-power. These have replaced direct-current motors, and the bills are no larger than they were with direct current for the same service. The power factor of these motors is between eighty and ninety per cent, according to size; or as high as can be obtained with two-phase and three-phase motors.

Mr. Insull spoke of the system here and the alternating system that was described, and wondered if I would advise changing such a station as the Chicago Edison to such a system as I have described. The question of which system to adopt must be controlled by the existing conditions; its economies must be taken into consideration in connection with the cost of the changes and the scrapping of old apparatus. It certainly could not be to the advantage of the Chicago Edison company to change its present system for general distribution for the downtown district here, where the bulk of lighting exists, to any such system as this, even if the efficiency were practically 100 per cent on the average, and I do not wish it to be understood that I would ever advise such a radical change. But in reaching out for new business in outlying districts, it has been proposed by Mr. Ferguson, and is already the practice in some places, to employ rotary transformers to produce alternating current, transmitting this to a distance at high potential and retransferring it to a low potential and through rotary transformers to direct current. This is a case where the system described could be used to great advantage. It seems to me absolutely unnecessary, under any conditions, to retransform from the alternating current to the direct current, and then to distribute with the three-wire system to outlying districts. Why not use the alternating current as it is? We can get a higher efficiency, and can accomplish all the purposes for which the direct current can be used. If a station that has been operated for some years is to be shut down and converted into a sub-station, and it employs a large number of direct-current motors and devices to do the work required of the direct current, involving a large investment, it might not be at all advantageous to change it to an alternating-current station; but for reaching out into new districts and developing them, it seems to me that there would be no reason for using the direct-current rotary transformer. The alternating current has been proposed for use in about this way for pioneer work, and when the three-wire system of distribution has been built up, to change over to direct-current work and put in rotary transformers. In doing this, we should gain nothing in efficiency, and in changing the system to direct current we should add greatly to the cost of the investment.

The Brooklyn Edison company has a station that has been in operation a short time where they have installed a large plant some six miles from the centre of distribution. They are generating alternating current entirely, three-phase, carrying it to their former centres of distribution and transforming it into direct current. The fact that they are doing this, and that the Chicago Edison company is preparing to do the same thing in some instances, shows that there is economy in moving the central station to one side of the district to be lighted, where real estate is cheaper, where water can be obtained for condensing and coal can be had cheaper; and in order to do that, in most cities, it is necessary to employ alternating currents, because the distances obviously become too great for the use of the direct current. Here in Chicago they have accomplished the same thing with the direct current, for the reason that they obtained a location about three thousand feet from the former centre of distribution. In most cities such an accessible location cannot be readily obtained; at least it was found so in Brooklyn. A station like the Brooklyn station could not afford to change its entire system over and adapt it for alternating current, so they could not use the alternating current direct from the large union power house without transforming to the direct current; and in such instances I would not advocate the use of any other system than has been suggested and put in practice by Mr. Ferguson. But in new installations and in rebuilding alternating-current central stations, this system finds its application, and in all new work where distribution is to be carried on over a large area,—as large as it is here in Chicago—I think it would be found advisable in every case, taking everything into consideration, to use such a system in preference to the direct-current system. Alternating current must be used for reaching the outlying districts. That requires the use of rotary transformers and the use of a different type of generator, as a rule, in the generating station, complicating the apparatus and the operation of the station, and requiring a great deal of additional investment in reserve capacity.

Mr. Insull referred to the claims of manufacturers several years ago not having been substantiated. The claims were made by manufacturers then, partly through the ignorance of the manufacturers, and partly through the ignorance of the purchasers; but we know all about the subject now, and there is no doubt that the drop in lines, the loss in transformers and the loss in distribution can be very accurately predetermined. I am not advocating an entirely new system from start to finish; I am basing the system on the Edison system, which has been in use for years, and which has been so well tried and found so successful; and the only change made in that system is the use of alternating current instead of direct current and high-potential feeders instead of low-potential feeders. The system, as a system of distribution, is not altered in any of its essential features, but simply involves the application of the alternating current for the purpose of reaching greater distances with economy. Mr. Insull wondered whether the company with which I am connected, if it were about to begin business in the district in which it now is, would use this system or the direct-current system; or whether it would not accomplish what it has accomplished at greater economy of operation if it had installed the Edison direct-current system in the first place. I would answer that our company would not be doing one-quarter the business it is doing to-day if it had been tied down to the direct-current system, pure and simple, and it could not possibly, with the Edison direct-current system, perform the service it has to perform to-day. The amount of business to be obtained in a given area is limited. The area in Chicago served from the Harrison street station is very small compared with the business to be obtained here in Chicago, or even in St. Louis; but we are not by any means so large a city as Chicago, though some of our people think we are.

THE PRESIDENT: It is from sixty to seventy per cent of the total lighting business in Cook county.

MR. WAGNER: We have to reach out five or six miles in almost every direction to get the business we have. I want to say, in answer to some of the statements that have been made, that in my opinion it is very undesirable to mix systems of distribution; to use both alternating and direct-current generators in the same or adjacent stations to accomplish the results desired. The multiplication of machinery and the additional investment for the reserve are very serious factors.

I spoke in my paper of the converter losses. I wish to answer Mr. Hubley in regard to that. In the most modern transformers made by several manufacturers to-day, they have almost eliminated the fatigue of the iron, and they will guarantee the increase in the iron losses to proceed at a very small rate. I said that in some instances the guarantee had been made that it would not increase over one per cent a year, and that where large transformers were used it would be inexpensive to re-anneal the iron of the transformers once in five or ten years, and that would bring the iron back to its former state.

I think Mr. De Camp will appreciate now that large transformers are the things to use wherever possible, and the larger the better.

In connection with Mr. Ferguson's pressure charts, I would say that I have seen many pressure charts taken from our lines that would compare very favorably, if not almost identical, with the best he has shown, and we use pressure wires in all cases. I think that Mr. Ferguson will tell you that no pressure wires were used even in the best of these alternating-current charts that he showed you.

MR. FERGUSON: That is right.

MR. WAGNER: You mentioned that the best chart was taken from a long circuit where a number of transformers were connected to secondary mains.

MR. FERGUSON: There were two feeders running from the station, feeding four large transformers. There were no pressure wires and no feeder compensator.

MR WAGNER: Mr. Walbank said something about the three-phase system. I do not want to say anything against it, but where lighting is the principal factor, the three-phase distribution cannot be made to regulate as well and give as satisfactory results as the single-phase or direct current. Mr. Walbank's business, I understand, is principally power. His motor business is greater than his light business, and in all the water-power plants he mentioned the current is furnished principally for power, and lighting is a secondary consideration. I could show you on the blackboard why it is impossible to regulate satisfactorily with three-phase circuits where the load varies differently on the different phases. It will vary in that way where lighting is the larger portion of the load, and will not where motors only are used. A regulator must be placed on each one of the three wires, if it is a three-wire three-phase system of distribution; and the regulator used to boost up the pressure to compensate for feeder and transformer drop on any one of the phases affects the adjacent phases practically the same as it affects that you wish to regulate; and it is impossible to avoid this except by the use of a four-wire system. With a four-wire three-phase system this may be very much lessened, if not eliminated.

THE PRESIDENT: Gentlemen, we have been kept so closely to it to-day that, with your permission, we will postpone until to-morrow morning the two papers that were scheduled for this afternoon's session. I should like to start promptly at ten o'clock. We have a good deal to do, and we shall undoubtedly have an interesting session.

ANNOUNCEMENTS

THE PRESIDENT: At eight o'clock to-night, Mr. Joseph Wetzler will deliver a lecture on "Electricity Direct from Coal." It is one of the possibilities of our business, and is a subject frequently discussed from time to time in the newspapers, and I think you will have a better appreciation of what you may read in the future if you will come and hear Mr. Wetzler to-night. I think you will find that he will give us a great deal of instruction.

MR. FERGUSON: If there are any gentlemen here that care to visit the main operating station of the Chicago Edison company at Harrison street, or any of the outlying stations, we shall be very glad to arrange to escort you to visit these stations at the close of this meeting. You will see some very interesting things connected with our operation. Those of you who are connected with alternating-current stations will see there the use of alternating currents by a direct-current company, and the direct-current men will see apparatus that I am sure will be useful to them in their business.

THE PRESIDENT: The railroad tickets for your return passage have been extended until the eighteenth instant, to enable you to go west with the Northwestern Electrical Association. If you will notify the secretary of that association, he will arrange for your tickets. Ladies will be included in the party.

With your permission, we will consider the meeting adjourned until ten o'clock to-morrow morning.

Adjourned.

ORDER OF BUSINESS

THURSDAY, June 9th, 1898.

FIFTH SESSION, 10.40 A. M.

1. Paper—"Cost of Producing Electric Power by Water Power from Lachine Rapids, Canada." By W. McLEA WALBANK
2. Paper — "Transformer Economy." By PROF. WINDER ELWELL GOLDSBOROUGH

SIXTH SESSION, 2.55 P. M.

1. Report—Committee on Standard Candle Power of Incandescent Lamps. LOUIS BELL, Chairman
2. Report—Committee on Legislation Concerning Theft of Current. JAMES I. AYER, Chairman
3. Report—Committee on Amendments to Freight Classification. JAMES I. AYER, Chairman

EXECUTIVE SESSION

1. Report—Secretary and Treasurer
2. Appointment of Committee on Legislative Policy
3. Report—Executive Committee
4. Election of Officers

FIFTH SESSION

President Insull called the meeting to order at 10.40 o'clock, announcing the first order of business to be the reading of a paper by Mr. W. McLea Walbank, of Montreal, Canada, on the cost of producing electricity by water power.

Mr. Walbank read the paper as follows:

LACHINE RAPIDS PLANT AND THE COST OF PRODUCING POWER FOR GENERATING ELECTRICITY THEREFROM

Mr. President and Gentlemen:

In order to allow of a fair comparison with other plants, of the cost of producing power for generating electricity from the Lachine Rapids plant, the writer considers it desirable to give you a brief outline of the hydraulic as well as the electrical equipment of our works.

The world-renowned Lachine Rapids, as you are all doubtless aware, are situated on the St. Lawrence River, a short distance from the city of Montreal.

The idea of converting the wasted energies of these turbulent waters and harnessing them for the use and convenience of man was not new. As far back as 1866 a company was formed, whose object was to erect dams and construct large hydraulic works about a mile lower down the river than the site of the present power house; their object being to induce factories to establish their works at the rapids, for at that date the possibilities of electric transmission had not been demonstrated. The scheme, however, never materialized, and since that date various projects have from time to time been talked of, but never matured.

In the fall of 1895 the Lachine Rapids Hydraulic and Land Company, Limited, commenced its operations. The directors began work only after having fully satisfied themselves upon the difficulties to be encountered and overcome, and carefully studying the question of back water, frazil and anchor ice, and went in with a determination to succeed. The company was honestly formed, without "ground floors" or "sub-cellars," with a bona fide capital, on which every share represents $100 in cash. This, the writer considers, has direct bearing on the cost of producing electricity, because a company handicapped by what is called watered stock, or exorbitant promoter salaries, has to pay interest on money it never had the use of. Having, therefore, formed a company on a solid and firm financial basis, the property fronting on the Lachine Rapids, and controlling the water-power privileges, was secured, and operations were begun for the development of the water power.

HYDRAULIC DEVELOPMENT

The hydraulic plant consists of a main dam and power house 1,000 feet long, and a wing dam and guard pier 5,000 feet long, forming a head race or basin with an average depth of twelve feet in low water. To secure this, it was necessary to divert the waters of the St. Lawrence and lay bare the bed of the river for a distance of over a mile and remove over four hundred thousand cubic yards of rock.

The main dam, which is constructed of a series of isolated cut stone piers, with head gates and stop logs, furnishing in all thirty-six flumes and three waste weirs, at the same time forming foundations for the power house and turbine sheds.

The total development will, when completed, consist of seventy-two vertical turbine wheels and twelve generators; the wheels connected in series of six, by gearing, to a horizontal shaft, at the end of which a generator is directly connected. The completed power house will contain twelve such sets; the whole as shown on the accompanying blue prints.

Of the total installation, forty-eight wheels are already in place, and the power house, head race, tail race and dams are completed.

ELECTRICAL EQUIPMENT

Each dynamo house will contain four three-phase General Electric alternators, wound for 4,400 volts at full load, and two direct-current exciters at 120 volts. There will be in the total installation three such dynamo houses, containing in all twelve dynamos and six exciters, each exciter being capable of exciting four machines. Each dynamo house will have its own switchboard, of blue Vermont marble, of the very latest design, so arranged that each circuit may be operated from the switchboard of either power house. The floors are of slate and the building of solid brick. The current is generated at 4,400 volts, avoiding the use of step-up transformers; is transmitted on iron poles over bare copper wire to the city of Montreal, a distance of about five miles, to the sub-stations, where the pressure will be lowered to 2,300 volts, and, by means of sub-station switchboards, subdivided into the desired units and distributed, partly through underground conduits, and partly by overhead construction, throughout the city of Montreal and its suburbs, where we find a population of over 300,000 people offering a market for light and power.

Of the total equipment one-third is already installed.

TOTAL POWER

The wheels were tested at the Holyoke testing flume, on April 16th and 17th, 1897, and developed at full gate as follows:

With a speed of seventy-six and one-fourth revolutions, discharging 235.33 cubic feet of water per second and developing 300.84 horse power; showing an efficiency of 81.32 per cent, which would make the total possible output of our power house about 16.000 kilowatts.

COST

Perhaps the greatest obstacle to a fair comparison of electric current produced by water power, as against the same current produced by steam, is the first cost. In the former case, especially if a large water power is to be developed, the expense of the whole installation, such as dams, head and tail races, etc., has usually been made at the beginning, while perhaps only a fraction of the power thus obtainable is at once used; therefore showing a very much larger capital cost per unit than with a steam plant, which need only install the power necessary for immediate demand and continue increasing or adding thereto as the demand therefor offers. In our own case you will notice it was necessary for us to spend about $1,000,000 in hydraulic development. This million dollars is able to furnish us over twenty thousand horse power, whereas it will be some time before we shall be able to convince the public of the advantages to be derived from the use of electricity, which is no easy task, as anyone familiar with the subject will bear out. From a commercial point of view the 5,000 horse power will have, for the present at least, to be charged with all the expense of the hydraulic development of over twenty thousand horse power.

In estimating the cost of producing power from the Lachine Rapids, the writer does not take into consideration the cost of distributing power, for this would be the same in either case, whether the prime mover were a water wheel or a steam engine. He will therefore confine himself to the cost of developing water power and delivering that power on the 'bus-bar at the sub-station, exclusive of the generator. He will add the cost of transmission line from the source of power to the sub-station in the city, because this is directly attributable to water-power plants, as it would not be necessary in the case of a steam plant, unless it were for transmitting power from a coal mine to a city, or following the practice laid down by the Brooklyn Edison company in locating their power house at a point convenient for obtaining coal and water at reduced prices, using high-tension transmission and converting by rotary converters at various sub-stations. There also will be included the step-down transformers to bring the pressure equal to that required for local distribution, namely, in the neighborhood of 2,000 volts. He will also charge the water power with the drop or loss in power from the rapids to the sub-station.

The writer therefore considers, in justice to the Lachine Rapids plant, that it would be necessary to give, first, the cost per kilowatt per year for the portion of the plant at present installed and connected to generators ready for operation; and, second, what the cost will be per kilowatt per year when the whole water-power development is in operation.

1st. The total cost of water rights, dams, hydraulic machinery, power house, transmission line, step-down transformers, etc., is $957,200.

Power developed, 4,000 kilowatts at the generator.

Allowing ten per cent loss, there will be delivered at the sub-station 'bus-bar 3,600 kilowatts, which is equivalent to $263.83 per kilowatt, capital cost.

This, at six per cent, would be equivalent to	$15.95 per K. W.
Depreciation of $300,000, which will more than cover the cost of that portion of the plant subject to depreciation, rated at five per cent and spread over 3,600 kilowatts, would be equivalent to	4.17 per K. W.
Operating expenses, including labor, repairs, insurance, amounts to $10,275 per annum, which, divided into 3,600 kilowatts, is equivalent to	2.85 per K. W.
Making a total cost per kilowatt on a twenty-four-hour-day basis per year	$22.97 per K. W.

2d. The total cost per kilowatt with the whole water-power plant in operation.

Before giving these figures the writer would like to explain that the figures herewith quoted are reliable for the cost of the completed plant, inasmuch as the same is at present under contract with reputable firms, the Lachine Rapids Hydraulic and Land Company having a limited time in which to order the works completed.

The total capital cost with seventy-two wheels installed will be $1,113,273.

Power developed after deducting all losses will be 13,500 kilowatts at the sub-station 'bus-bar, equivalent to $82.46 per horse power capital cost, which at six per cent represents (per annum)	$4.95 per K. W.

Depreciation per kilowatt will equal...	$1.68 per K. W.
Operating expenses, including labor, repairs, oil and waste and insurance, if taken upon the same basis as already existing, will amount to $20,453, equivalent to...........	1.51 per K. W.
Making a total for a twenty-four-hour run per annum of..............	$8.14 per K. W.

It will be noticed that the operating expenses, as well as the depreciation per kilowatt, in the latter case is very much reduced; and it is a remarkable feature how constant our operating expenses are, even at present, being practically the same with full load as with no load.

In connection with these figures it might be stated that coal used in Montreal and vicinity is what is known as Nova Scotian coal, and costs $3.50 per ton for run of mine.

The writer would also draw your attention to the fact that the capital cost cited in each of the foregoing cases includes money paid for real estate, of which the company owns over some eight million feet, fronting on the rapids, intended at some future date to form the site of a suburban town, and which it is hoped and expected will return the money expended in developing the water power above referred' to.

CONCLUSIONS

From the foregoing the writer trusts that he has shown that where reliable water power can be obtained within reasonable distance from power centres it can be made to produce cheap electric current, to say nothing of the great advantages the city must derive therefrom, not only commercially, but viewed from a sanitary standpoint as well, as the use of electric power thus generated is the best smoke consumer yet invented.

DISCUSSION

MR. WAGNER: I wish to ask for information on these figures. Are they based on a twenty-four-hour use of the kilowatt capacity of the generators or of the station? In other words, I want to know whether the figures are based on the assumption that the generators are loaded practically at their maximum rated capacity for twenty-four hours for each day in the year. If these figures were based on that assumption, and we took the average load factor of most of our central stations, of from twenty per cent to twenty-five per cent of the maximum load, would it not have increased these costs four or five times, based on the number of kilowatt-hours delivered from the station? I understand that these two costs are based on the kilowatt capacity of the station, and not on the average kilowatts delivered; that average being, say, from twenty to twenty-five per cent of the maximum, which cannot exceed the maximum capacity of the generator.

MR. WALBANK: The cost that I have given you there is based upon the possible output of a plant, independently of the number of hours that it is used. Our capital cost was a stated amount, and we have a certain capacity in electrical generators; by dividing one into the other, you get how much it cost us per horse power to develop. But, so far as twenty-five per cent use of the system is concerned, we hope to run pretty nearly full all the time. It does not cost any more to run during the daytime for power and during the nighttime for the lighting load.

Mr. Wagner: It does not cost any more to do that, but you are trying to perform practically the same service that the existing central stations in large cities do from their steam plants. You have the same service to perform, for lighting and power, over a large city, and supply current for that purpose as it is required; and it is found that the average current thus required is only twenty or twenty-five per cent of the maximum requirement, and the maximum requirement cannot be greater than the maximum capacity of the generators; so that it is a physical impossibility to find a service that will keep your generators loaded. Therefore, the cost of production, per kilowatt, must be based on the cost of production of the kilowatt-hours per year delivered, and not on possible kilowatts, which could be delivered, if you could find people to use your current constantly at all times, at a uniform rate of use.

Mr. Walbank: I believe that, sooner or later, we shall keep our plant running pretty nearly full capacity. There is in use in Montreal at the present time over thirty thousand horse power of steam. We have the street railway company, using 5,000 horse power in steam, besides a suburban street railway, using from five hundred to seven hundred horse power. There is also the opening and closing of locks and drawbridges on the Lachine canal, and who knows but in the near future we shall be able to do the towing in this canal. If we chose to sell our power cheaply enough, there are certain manufacturers who would take our power when not required for lighting.

Mr. Wagner: Take, for instance, the best users of power on the average—the machine shops and factories. They use it only an average of ten hours per day; they do not run at night. In the example which you give of street-railway power plants, the load is very fluctuating, and usually reaches a minimum in the middle of the day and the middle of the night and the maximum in the morning and the afternoon. You cannot with such loads obtain a uniform load on your generators. If these different characters of work might be made to be performed together from the same generators, it would give you a little better average load than any one of them separately; still, they would overlap, as a rule, at the maximum, and that overlap is the element that determines the capacity for which your generators must be reserved.

MR. WALBANK: To get over that, we should give power at lower rates to be used from seven o'clock in the morning until four o'clock in the afternoon and from seven in the evening until four o'clock in the morning.

THE PRESIDENT: That would not escape an overlap. Suppose you got all the power generated at the present time in the city of Montreal, and plotted a curve; you would find that the curve would start to rise in the winter towards three o'clock and would not go down until about a quarter past five, and at night it would go down to a small percentage of the maximum. That is, if you got every particle of power used in Montreal, including twenty-four-hour power, lighting, pumping, street-railway power and arc lighting, you would find that you had a high maximum in the winter, and it would follow closely the curve of any large central station in the central portion of any city.

MR. WALBANK: During last winter, for instance, our demand for lighting did not begin until four o'clock p. m., and very seldom as early as four o'clock.

Mr. Wagner: You cannot make people use current because it is cheap; they use it when they want it.

Mr. Walbank: We had a contract with a cotton company to run their plant from seven in the morning until four in the afternoon during the winter months, and at any time they wanted the power during the summer months, and if they found that it would pay them to take it they would do so. We could give them power so cheaply that it would pay them That contract would have been closed, except that there was question of a guarantee. They wanted us to be responsible for the firemen cutting wires, and to assume extraordinary responsibility, which we would not do. We offered to sign a contract that any other electric company would sign.

Mr. Ferguson: It seems to me that the figures $10,275 per annum are very small for the operating expenses of such a plant as described by Mr. Walbank. The figures on the cost of the kilowatt-hour are based on full load, running the machinery at full load twenty-four hours a day. That would give an output of 31,000,000 units a year, which is double the output in Chicago, and I am sure we could not begin to operate our plant for anything like that amount. I do not see how it can possibly include any portion of the general expense.

Mr. Walbank: Mr. Ferguson does not understand the point; my paper does not treat of the production of electricity, but the production of power for generating electricity. It is simply the operating expenses of the power station at the Rapids. All that is required to operate that plant to-day is three switchboard men; one day man at the water wheels, one night man at the water wheels and a man to clean around. The figures are actually taken from our books.

THE PRESIDENT: Suppose a man wants power for three or four hours a day; will you sell it?

MR. WALBANK: Yes, for a minute a day if he wants it; at any time he wants it, flat rate or by meter; one lamp or 5,000 horse power.

THE PRESIDENT: How are you going to protect yourself on the question of maximum load; by difference in rates?

MR. WALBANK: We have, of course, difference in rates.

MR. WAGNER: Mr. Insull showed us forcibly day before yesterday, on the diagram which he discussed at some length, the large proportion of the interest charge compared with the total cost of operating, all expenses included. The only saving to be effected in water-power distribution, as compared with distribution from central stations from steam, is the item of coal.

THE PRESIDENT: That is one-sixth of the interest; that is all.

MR. WAGNER: Now, can a water-power plant be installed that will not cost more than one-sixth more than a steam plant? If the water-power plant costs one-sixth more than the original cost of installation of a steam-power plant, the cost of operating it will be the same, I take it.

MR. WALBANK: How about engineers, etc.?

MR. WAGNER: The labor item that would be eliminated by the use of water power would necessarily have to go into the fuel account, or be treated as an equivalent for the fuel account, and we might increase that to one-quarter instead of one-sixth, and assume that the water-power plant cost twenty-five per cent more than the steam plant, in which case the cost of operating and the production of current per kilowatt-hour would be approximately the same.

Mr. Walbank: Then, there is depreciation on the steam plant as compared with nothing on the water plant.

Mr. Wagner: We have not included all the depreciation charges in the discussions we have had on that subject heretofore, except such depreciation as is taken care of in the continual maintenance of the plant when we refer to operation. I do not want to criticise the system unfavorably, but simply desire to get information on the comparison of the cost of production by water and by steam power.

Mr. Ferguson: To compare such a water-power plant as described by Mr. Walbank with a steam plant, I should like to offer as a permanent installation one equal to that outlined by Mr. Walbank —our system in Chicago represented by the Harrison-street station; and I think all who have seen that plant will agree that that station is quite as permanent, from the standpoint of investment, as the system outlined by Mr. Walbank. To show the comparative cost of producing a kilowatt-hour, I should like to offer some figures. The cost of the station, including the transmission line, is $1,200,000; the interest on that amount will be $72,000; the total cost of operation at the switchboard of that station is $77,000 per year; the two latter items added together make $149,000. Taking the same percentage for depreciation that Mr. Walbank takes, we have a depreciation of $20,000, making the total operating cost $169,000. The total maximum capacity of that station is 7,000 kilowatts, so the cost per kilowatt in that station would be $24, as compared with $22.90 stated by

Mr. Walbank; so that the difference between cost in generation in a water-power plant and that of a first-class steam plant is very slight.

MR. WALBANK: What price do you pay for coal?

MR. FERGUSON: A dollar and twelve cents a ton.

MR. WALBANK: We pay $3.50 a ton.

MR. FAKES: What is the difference in depreciation between the water-power plant and an ordinary steam plant?

MR. WALBANK: I cannot tell you what the depreciation of a steam plant is, but so far as the depreciation in a water-power plant is concerned, there is practically nothing to depreciate; I do not think our expenses for depreciation amount to anything. There has been no great improvement in water wheels for twenty years. If you compare the water wheels of twenty years ago with those manufactured to-day you will find very little difference. I put in water wheels twenty years ago on the Lachine Canal, Montreal, and those we put in to-day are practically the same.

MR. WAGNER: It would seem that the statement that has been made, that there have been no improvements made in water wheels during the last twenty years, would tend to show that the water-wheel manufacturers have not been so progressive as some of the manufacturers in other lines.

MR. WALBANK: The water-wheel manufacturers are ahead of them in perfecting their wheels.

MR. WAGNER: I heard it stated two or three years ago by a prominent manufacturer of arc-light machines that they had made no changes for nearly ten years in the patterns from which their arc-light machines were made.

THE PRESIDENT: Are they in business now?

MR. WAGNER: They are not in business now. I make the statement to show how systematically the water-power business must have been conducted, and how little necessity they have found for changes in their business.

MR. DAVIS: I ask whether Mr. Walbank has made any calculation as to the cost of power on the basis of operating 3,600 kilowatts six hours each day, including Sunday, and 900 kilowatts for eighteen hours.

MR. WALBANK: I am not writing on the cost of distributing power, but on the cost of generating power.

MR. DAVIS: I wanted to know as to the fact whether any calculation had been made on the basis suggested of a maximum load of 3,600 kilowatts for six hours and 900 kilowatts for eighteen hours.

MR. WALBANK: We shall probably be able to answer that question in five years, after we have had enough experience.

MR. DAVIS: Have you made any contracts for less than two cents a kilowatt, delivered at the factory?

MR. WALBANK: We do not sell our power in that way. I will explain our method of selling our power; it depends on the unit, whether it is one horse power or 500 horse power.

MR. DAVIS: Your best customer?

MR: WALBANK: We give it to him by meter; a ten hours' run, at a certain figure for the year. In that case there is a scale of charges, which vary from $35 a horse power down to $10 a horse power, and then so much a kilowatt-hour for what the meter shows.

MR. DAVIS: What is the kilowatt charge?

MR. WALBANK: It varies from one-half cent to four or five cents; depending on the probable use to be made of the current.

I think that in these figures Mr. Walbank has left out an important thing. We ought to know what the load-factor of the system is, because the figure of $10,000 is proportional with his output, or it will vary with the output, so that the load-factor is now only ten per cent. It is hardly fair to compare the cost he has presented with that of a system having a load-factor of twenty-five per cent. I took a station of twenty-five per cent. If it were only ten per cent, then, of course, the output per kilowatt would be less, and the figures would be still more favorable to the steam plant.

MR. MATLACK: There is a water-power plant not far from Chicago. It was started with four No. 10 old-style Edison machines, and the theory was that it would cost very little to operate it. The experience they had with the water-power plant—with the interruption and unreliability of it—made it necessary to displace it with a steam plant. The difficulties were from obstructions getting into the wheels' ports and making it impossible to shut the water off. As the load went off, the speed and voltage increased beyond control, and burned out the lamps; anchor ice would also clog up the racks in front of the wheels and shut the water off; and another difficulty was that a school of eels once went into the wheel, clogged it so that water could not pass and shut down the plant. The other water-power users on the race had a custom of letting the water out of the head race two weeks each summer for cleaning out the wheel pits, and it made it very inconvenient for the electric-light customers. As has been stated, these water-power plants, for economy of construction, must be built and investment made for the maximum capacity of the water power. Most central stations have started in with a few hundred horse power and have grown up to many times their starting load. Under these conditions the interest charges on the original investment of a water-power plant must be earned by a light load,—only a small fraction of the plant capacity—and the water-power plant would therefore be a very expensive investment unless the investment were light or there were business from the first to use the full capacity of the plant.

MR. WALBANK: Had the water plant you refer to any rack in front of it? How did the eels get in?

MR. MATLACK: They went through the rack; they took out ten bushels of them.

MR. DAVIS: Does Mr. Walbank expect to do much business in the case of small customers on $35 per year per horse power and four cents a kilowatt-hour, which means for small consumers about $120 a year plus the basic rate? It is the experience of the majority of central stations that, taking everything into consideration, we should be only too glad to do a power business on that basis independently of the basic rate. In other words, our experience in our town has been that, with the competition of isolated plants, we have to sell current at three and one-half cents per kilowatt, net.

MR. WALBANK: In reply to the question as to the cost of a single horse power; if the customer is going to use it ten hours a day, he is not going to pay meter rate, he will take it on flat rate. On the other hand, if we supplied him on the meter rate without a standing-by charge, he might use it only an hour and we should get practically nothing at all from him, notwithstanding the fact that we should have to stand ready to give him the full quantity of power he needed at any moment. For this reason we make a standing-by charge for small units of $35 per horse power, and charge him so much per horse-power hour for the amount consumed as shown by the meter. This standing-by charge decreases as the unit increases.

MR. WAGNER: I think we all appreciate that within the next few years water-power stations will be developed over the country to a very great extent, and we are all very much interested in the engineering details that have been so neatly worked out by Mr. Walbank in Montreal. This undoubtedly stands as one of the foremost electric water-power installations thus far produced; but when it comes to the cost of operation and distribution, and of the total cost per unit of power furnished from such installations, we should like very much to see them based on lines somewhat similar to those upon which we are accustomed to have the records of steam-power plants. We have a more or less uniform system among our central stations for showing the cost of production per kilowatt-hour delivered from the station, and if the water-power plants could use the same general forms to show their total costs, the comparison would be more instructive.

MR. DAVIS: What would be your price to a customer that would guarantee to use 100 horse power for ten hours a day per working year; what would the rate per horse power be?

MR. WALBANK: Anywhere from $32 to $36.

MR. RICE: I was sorry to be called out of the room at the time the paper was read. I should like to ask what the regulation is in the station that is comparable to the charts given yesterday by Mr. Ferguson.

MR. WALBANK: You mean electrical regulation of water wheels?

MR. RICE: I should like information respecting the regulation of the water wheels and also the regulation in the lighting system.

MR. WALBANK: So far as the electrical regulation is concerned we have none, because we only opened last December and the special station switchboard is not up yet. What our ultimate regulation will be is pretty hard to say. I wish to correct a remark made by Mr. Wagner yesterday when he said that we operated principally for the supplying of power. We are operating about 30,000 incandescent lights now, with very little power. We have 300 series arc lamps, seventy-five to 100 alternating arc lamps, with one or two of the inclosed type. We were originally operating a single-phase plant from steam, and we found then what our coal costs us. We shut down the steam plant and started up the three-phase plant from the Rapids, and used the same switchboard that we were operating the steam plant with, and converted our power down to the two-phase and connected on that switchboard and brought out one leg in one direction and the other leg in the other direction. We are now operating with the same generator another plant at the northeast end of the city and through the suburbs of Montreal, and I do not think we have any complaint of the regulation; and the three-phase is as good as single-phase for every purpose.

MR. ANDERSON: I represent a company located at Springfield, Massachusetts. One year ago we completed a water-power installation of a capacity equal to that of the steam station that we ran before. I found that with a maximum capacity of water wheels of 2,800 horse power we were able to deliver 1,000 electrical horse power six miles from the water-power station. I also found that it cost $6,000 to operate that station. According to my calculation, that is about $8 per kilowatt, delivered, for operating expenses. These operating expenses do not include any cost of repairs, which have not yet been necessary. My company pays the company owning the water-power privileges $9.23 a mechanical horse power delivered to its shaft. To deliver an electrical horse power at the end of the line, deducting for losses, costs us about $12. That makes it $21.23 for an electrical horse power delivered, with no allowance made for depreciation or the cost of repairs or interest. The company built a power station costing approximately $150,000, with a capacity of 2,800 horse power. The electric-light company pays to the corporation owning the water-power privilege an amount of money representing an investment of about $200,000. The depreciation factor we can only guess at, but we allow for depreciation a sum of money, the interest on which amounts to about $5 per electrical horse power delivered. I may say here that the load on that station consists of some seven hundred 1,200-candle-power street lamps, which burn 4,000 hours a year, all night; a maximum incandescent load of 600 amperes or 720 kilowatts, and a motor load, which is on from seven o'clock in the morning until six at night, of about two hundred horse power, besides a load of 200 horse power of commercial arc lighting; so that we take in all classes of work. We find that with our maximum of 2,800 horse power, which represents the maximum load at the water-power station, we can deliver twenty-four hours a day an average of 1,000 horse power.

MR. DAVIS: I ask the last speaker if he is willing to state the difference in the net result to him before and after installing and operating the water-power plant.

MR. ANDERSON: We have found that the change from the steam plant to the water-power plant has resulted in a very considerable saving, due to very favorable conditions; and we have also found that we are able to deliver nine-tenths, approximately, of our whole sold output from the water-power plant.

THE PRESIDENT: As there seems to be no further discussion of this subject, I take great pleasure in calling upon Professor Goldsborough to read his paper on transformer economy.

Professor Goldsborough read the following paper:

TRANSFORMER ECONOMY

A great deal has been said and written about the static transformer of alternating currents, and yet we are only just beginning to understand this much-discussed piece of apparatus. The manufacturers have made it and experimented with it, the theorists have experimented with it and disputed over it, the underwriters have disputed over it and endured it, and the central-station men have endured it and made use of it to the great good and comfort of the public. No other piece of apparatus in the field of electrical engineering has been lauded higher or been the subject of greater abuse, and to all it has served a purpose. The transformer occupies a higher position to-day than ever before, and it grows in importance as each new development in the field of applied electricity points out a new department of usefulness for it.

There has, however, been enough agitation lately on the part of manufacturers, in behalf of substituting new types of transformers for the old ones now in use, and of relegating the small transformer to the scrap heap, to cause some unrest to the central-station men that are responsible for the successful operation of alternating-current generating plants. The foundations of many of these plants were laid before the time of skilled designers of electrical machinery, and at a period when the factory motto was "cut and try." As the public demands increased, the plants developed and expanded before the practical men were amenable to "theories," and before the exact methods of the laboratory had become the daily practice of the constructing engineer. Managers see that engineers are still making mistakes, and that faulty design is still a factor in electrical development; and when they call to mind the enormous sums of money that have been spent in this country on ill-advised improvements, it is not to be wondered at that they hesitate.

There is, however, a gradual change for the better in the number of the yearly contributions to the records of our electrical societies, and as these records are the expression of the best thoughts of the men that have made America famous as the land of electricity, they may be taken as signs of the times in our department of engineering activity.

We are constantly impressed with the fact that the refinements of exact scientific methods are being made the subject of everyday discussion, and that the more difficult problems of the technical side of the profession are being so well elucidated by our "practical theorists" that it is possible for all of us to enjoy a concrete appreciation of electrical science without an excessive expenditure of mental energy on the theoretical. We are coming to a time when exact methods will be the universal rule and when the reputation of having a high "guessing factor" will no longer be a sufficient recommendation. These influences are noticeable in the improved electrical intelligence of our workmen, as well as of our station engineers, and I find that it extends even to the general public. Indeed, a careful record of the number of times that I am asked, "How does the little trolley wheel push the car along?" shows a yearly decrease of nearly fifty per cent. So we see that matters adjudged to be of slight importance a few years ago are being allotted their normal position. A fault is a fault at the present day, and is not often disregarded as "too small to be appreciable." The old saying that "if you take care of the pennies, the dollars will take care of themselves" applies just as well to electrical engineering as it does to other professions, and it is the pennies that I am about to deal with.

Our principal manufacturing companies freely advertise and guarantee the specific economic performance of which each and every one of the transformers that they place upon the market is capable. They severally advertise to supply us with transformers equaling in efficiency, regulation (and what not), any other transformer that can be found upon the market. The manufacturing companies are unanimous in their guarantee of high efficiency, low core losses, negligible aging and close regulation. If we can purchase transformers freely on these representations, with sufficient guarantee that the specifications advertised are strictly conformed to or improved upon, there is little to be desired on the part of the purchaser over and above what is offered. Any slight improvement that it shall be possible to make upon the best of the performances advertised by the competing factories will be forthcoming in consequence of the rivalries of trade, and the purchaser need only seek now for means of protecting himself against occasional faulty manufacture.

When, therefore, we consider the perfection to which this type of apparatus has been brought, in its every detail, and in sizes varying in capacity from a fraction of one to over eight hundred kilowatts, we have cause for congratulation. If you have followed the design and manufacture of the commercial transformer, I think you will admit that at the present time the best of them are figured just about as close as is possible; and, in fact, we have almost reached the point beyond which any further advance in the direction of improved efficiency must be made by getting better insulating materials, requiring less space and giving this space to the iron and copper.

With a view to investigating the present status of the transformer and the ability of transformer manufacturers to meet in all cases the exacting specifications which they have laid down for themselves, I have had a number of transformers of recent design tested in the Purdue laboratories within the last year. The results of these tests are especially gratifying when gauged from the standpoint of our present commercial requirements, and to the specialist a detailed statement of the results would be interesting. In view of the fact, however, that the electrical literature of the day contains numerous matter of this kind, I will not bore you with many figures, but will rather discuss the results in a general way.

With but one exception the transformers tested have surpassed the requirements of the specifications laid down by Professor Jackson in his excellent article on transformer testing, with which we are all familiar, and, generally speaking, they have conformed fairly closely to the published guarantees of the companies submitting the transformers for test. To what extent this is true may be better appreciated if I cite one or two examples.

A 2.5-kilowatt transformer was submitted for test, which was guaranteed to conform to or improve upon the following specifications: Core loss, forty-eight watts; regulation, 2.1 per cent, and full load efficiency, 96.1 per cent. The test of this transformer gave, core loss, 42.19 watts; regulation, 1.9 per cent; full load efficiency, 96 2 per cent. The showing made by this transformer is good. The core loss is 5.81 watts less than the stipulated value, and the efficiencies are in excess of the stipulated values. In this case the manufacturers more than substantiated their guarantee, and supplied a transformer that is a greater revenue producer than the specifications call for. If the core iron of this transformer can be relied upon as not materially increasing in its hysteretic loss with age, it is an easy matter to figure the money value of the excess economy that the transformer develops.

Suppose, for instance, a contract should be made for forty of these transformers at $30 each, to meet an increase in a station load of 100 kilowatts. On an all-day schedule these transformers would probably carry a commercial load equivalent to full load working for five hours. This assumption may seem to represent a better condition of service than is usually met with in practice, but it is an assumption that is fair to the manufacturer in considering the all-day efficiency. The transformers would therefore be working under no load for 6,935 hours and under full load for 1,825 hours per year, and under the conditions of the test would save 1,794 kilowatt-hours to the station. If we figure the cost of producing this power at two cents per kilowatt-hour, the saving per year would be $35.88 for the forty transformers, or practically three per cent on the amount invested in the transformers. If this power were sold for six cents per kilowatt-hour, it would represent a net gain to the purchaser of $107.64 per year more than he had any right to expect under the contract specifications.

Another 2.5-kilowatt transformer submitted for test is advertised by the makers to show a core loss of fifty-seven watts, a quarter-load efficiency of ninety-one per cent, a full-load efficiency of ninety-six per cent, a regulation of two per cent, and a no-load current of one-tenth of an ampere. Under test it was found to have a core loss of 63.6 watts, a quarter-load efficiency of ninety per cent, a full-load efficiency of 94.8, a regulation of three per cent, and a no-load current of .087.

Suppose we estimate the economy of transformers of this type just as we did those of the type previously considered. The forty transformers, working on the same schedule, would waste 4,014 kilowatt-hours more power than they should under the specifications advertised. At two cents per kilowatt-hour, the total money loss would be $80 per year, or over 6.5 per cent of the cost price of $1,200.

Many engineers may claim that the cost of checking up the performance of the transformers would more than eat up the saving effected by the small margin that these results represent, and in many cases under the present organization this would doubtless be true; but if a well-advised stand were to be taken by the central-station managers for mutual protection, the result would be markedly beneficial. A percentage of the transformer output of each of the manufacturing firms could, for instance, be tested in some one place, where a record of the individual performance of all the transformers submitted for trial could be kept, and not only efficiency, but aging and insulation and temperature trials could be made at a merely nominal expense.

But these examples do not cover the ground. I will cite two others.

In the case of a fifteen-kilowatt, oil-insulated transformer, guaranteed to develop a quarter-load efficiency of ninety-six per cent, a full-load efficiency of 97.4 per cent, and to have a regulation of 1.77 per cent, the test showed a quarter-load efficiency of 94.5 per cent, a full-load efficiency of 96.1 per cent and a regulation of 1.6 per cent. The core loss of this transformer, which operates at sixty cycles, is 186.6 watts, and the specifications under which it was built require that the core loss should be about 150 watts. It would take seven of these to give an output of 100 kilowatts, and they would cost not less than $115 each. The seven transformers in this case would waste 3,855 kilowatt-hours in a year, which represents a financial loss of $77 in one year, over and above the loss to be expected. This approximates ten per cent of the original cost of the transformers, and is an item that cannot be neglected. If, on the other hand, this waste power could be sold at six cents per kilowatt-hour, it would represent a part of the just return on the investment contemplated when the transformers were purchased, and would mean $221 to the company. I do not claim that the figures which I present to you cover all the items of expense that enter into the installation of 100 kilowatts in transformers. They do not; but they do represent a phase of the question that deserves more than passing attention at a time when competition is becoming sharper and sharper.

In what I have thus far said I have not touched upon the matter of the aging of the transformer core-iron. In cases where it is appreciable it only serves to aggravate the conditions and make the percentage loss greater. In the same way, the cost of production and the selling price of the power both enter as important factors, as well as the cost of the transformers. All of these assumptions I have placed low, and they should be regarded rather as pertinent examples of the conditions that exist in large plants. The small plants will be affected by influences of this character to a much greater extent.

I do not wish to tire you with figures, but, as I believe you will be interested in these comparisons of guaranteed and actual efficiencies, I wish to call your attention to one case more before leaving this matter. Not long ago a manufacturing company requested permission to send a one-kilowatt transformer to the University laboratories for a special test, as the tranformer was of a new type and highly efficient. There was no direct guarantee in this case, but the impression was given that the transformer would develop an efficiency equal to, if not exceeding, the efficiency of any other transformer of like capacity on the market. The results of our tests indicated a core loss of 178 watts, a full-load efficiency of 83.6, a quarter-load efficiency of 62.4 and an all-day efficiency of only 54.5 per cent. There are probably to-day a goodly number of these so-called "highly efficient" transformers eating up the profits of various of our lighting companies throughout the country, simply for the reason that in many cases business managers of electric light and power plants are not sufficiently alive to the importance of looking after the efficiency of the apparatus forming their equipments just as closely as they look after and check up every item of operating expense and maintenance that is necessitated by the exigencies of the service.

The use of such transformers as the one just referred to would be pitiable. It is fortunate that they do not grow to large proportions, but nevertheless they have a telling effect wherever they fall.

As regards the aging of the modern transformer irons, I hold rather a conservative opinion at the present time. A great deal has undoubtedly been accomplished within the last few years in the way of improvement in this respect, and the modern transformers that are supplied to us for testing show a wonderful gain in efficiency, due both to the lower initial core losses and to the diminished per cent of increase of these core losses with the aging of the iron. The general opinion seems to prevail at present to the effect that aging is due directly to the reversal of the direction of the flow of the magnetic flux in, rather than to long-continued heating of, the iron forming the cores of transformers, and this opinion is also expressed in much of the printed matter that has come into my hands.

In a recent lecture delivered by Professor Fleming, he said: "It was also discovered, some time back, by Mr. W. Mordey, that prolonged slow heating of iron to only sixty degrees centigrade or ninety degrees centigrade has a marked effect on the hysteretic constant, and the result is often to increase this constant two or three times. The effect varies with the annealing of the iron, and in many cases the iron which shows the least hysteretic constant at starting, experiences the largest percentage increase of it on prolonged heating. This effect is called the magnetic aging of the iron. Owing to the enormous use of iron for transformer purposes, this aging has now become a very important matter.

"The electrician lays no very great stress on the mechanical qualities, such as tensile strength, elasticity and so on, but he requires high permeability, small hysteretic constant and small aging; and the iron and steel manufacturer has been able of late years to meet these new requests by producing steel of the necessary quality. Iron and steel can now be produced with a maximum permeability of 4,000 C. G. S. units, a hysteretic loss of about .15 of a watt per pound per 100 cycles per 2,500 flux density, and of non-aging quality. I do not mean to imply that all these qualities can be equally combined in the same sample, but that the iron or steel can be varied to suit the demand.

"Steel can be produced with a higher permeability than wrought iron for large magnetic forces, and with a superior non-aging quality."

The fact seems to be well established that non-aging transformer iron is a commercial possibility, but the fact remains to be demonstrated practically that material of the necessary quality can be obtained in sufficiently large quantities to supply the demands that are being made upon the manufactories. Failure in this regard is not the fault of the builders of the transformers, and I have reason to know that there are cases in which disquiet prevails in the minds of managers as to whether or not they are getting what they are paying for. I know that the general claim is made that iron with an "inappreciable aging effect" is used, and I do not wish to go on record as claiming that it is not used; but what I do wish to point out is that there are transformers being placed on the market to-day that do not contain non-aging iron. From a large transformer company I have received notice that "at the present time we have not non-aging iron that will fulfill our specifications of core loss; that which we have on hand will give a core loss of from twenty per cent to twenty-five per cent greater than the amount stated in our specifications." At the present time, therefore, it is needful to make just as careful tests for aging as for efficiency or for insulation, in spite of the fact that the former take a longer time and are therefore relatively more expensive to make.

During the last three months six transformers of different types have been subjected to most carefully conducted aging tests in our laboratories. The completed report on these tests has come to me within the last few days, and I can give you a résumé of the results.

The core losses of transformers A and B were high to begin with, the first being seventy-two watts and the latter eighty-three watts. The per-cent increase in the core loss of these two transformers does not, however, seem to be as great as the per-cent increase in the core losses of transformers C and D, which are of more recent manufacture, and which showed initial core losses of 31.5 and 37 watts, respectively. Transformers B and D are of 1.5 kilowatts capacity, and transformers A and C of 2.5 kilowatts capacity. An increase of from five to ten per cent is shown in the core losses of all the transformers.

To get an idea of what this means, suppose we consider the effect upon the economy of the 2.5-kilowatt transformers, considered in the second case discussed above, of a ten per cent increase in the core loss. It will add $1.11 per year to the cost of operating each transformer at two cents per kilowatt-hour, or $4.44 for the total number. This represents an additional gain of 3.7 per cent per year on the investment in three months, or a possible percentage loss on the investment of 14.8 per cent after the first year, on the supposition of a uniform increase in the core loss. These figures are not startling in any way; they are too small for that; but they are matters of fact to be taken into consideration when making investments. The opinions that I am voicing regarding the aging of modern transformer irons are conservative, as I believe the transformers built to-day will show a marked improvement upon the performance of transformers built even as late as one year ago. So far as the aging tests that we have made go to throw light upon the subject, I am inclined to believe that the aging problem has not as yet been solved, as none of the transformers tested have met the requirements of the specifications under which they were submitted, and some have fallen very far short of it. All of the transformers tested were new except transformer A, which, at the time these tests began, had a core loss already increased to thirteen per cent above its initial value. Transformer A was built about two years ago.

The aging of transformer iron does not increase at a constant rate with the time. The rate of increase diminishes as the service continues, but the increase may go on indefinitely. Until the use of non-aging iron becomes more generally possible than at present, it is probable that it will pay to replace the majority of the transformers placed on the market by new ones every few years.

It is our present intention to inaugurate next fall a series of one-year aging tests under continuous full-load conditions of a representative number of transformers that will be built during the present summer by the manufacturing companies that are interested in having these points thoroughly ventilated, and I trust to be able to publish a record of fine performance in this respect at the time of the completion of the tests.

The correct insulation of transformers is another important point that should be considered by the central-station manager. Like many of the problems with which we have to deal in the effort to make the transformer a commercial success, this one seems to be subject to a wide variety of opinion. The oil insulation of transformers has deservedly come into great favor, and where care is taken in the selection of the oils used and in the proper design of the transformer case, high protection is secured. Oil insulation under all circumstances does not, however, secure to the purchaser the protection which he feels he is paying for. The claims that are usually made for the superiority of oil insulation, to wit., that it serves to preserve the insulation from oxidization, re-inforces the resistance of the insulation to puncture, re-insulates punctures after the passage of the discharge and facilitates the diffusion of the energy liberated as heat in the core and the coils,—can in general be readily substantiated.

My experience, however, is that these statements must be regarded as having only a relative bearing upon the subject. Under certain circumstances the insulating value of an oil will be very materially impaired. We are told that transformers will last indefinitely when insulated with oil, whereas without oil the insulation will be so deteriorated after five or ten years that the transformers should be replaced; and it may therefore be a matter of surprise that the insulating qualities of the oil itself are ever seriously diminished. As a matter of fact, experiment shows that the insulating properties of the oils commonly used in transformers are increased as their temperatures are raised up to about 110 degrees centigrade, and that if allowed to cool they will not lose their augmented power of resisting a disruptive discharge. As much as this might be said in favor of oil insulation, in view of this two- or three-fold gain in insulating power, were it not for the fact that a continued heating of the oil for any considerable length of time changes the oil to such an extent that on being cooled its breakdown value will be only about one-fifth of its original value. Therefore, an oil-insulated transformer that will stand an insulation test of 10,000 volts when new, may break down under a pressure of 2,000 volts after having been in continuous service for a considerable time. Conditions such as will produce a result of this character are not likely to occur in the case of modern transformers, as the increase in the temperature of even the poorest transformers rarely exceeds seventy degrees centigrade. I have, however, met with cases in which excessive heating has resulted when the transformers were kept continuously in service, and I have also in mind a case in which a good modern transformer was so situated, above a tin roof and in a position where it was protected from any breeze that might be stirring, that, when the sun played upon it, its temperature reached perfectly distressing values.

What I have said will serve as a hint of how not to handle a transformer, and the importance of selecting proper places for the location of transformers. If you will look carefully into the matter, you will find that not all of the burnouts are due to faulty construction on the part of the manufacturer. It is my experience that the contractor has been in fault in a fair proportion of the cases in which the transformer and service installation has suffered.

For all commercial purposes the best oils will be found to give thoroughly satisfactory results and retain their insulating properties unimpaired as long as the maximum temperature of the oil does not exceed sixty or seventy degrees centigrade. In making a station test of a transformer, if the rise in the temperature of the windings, as measured by the increase of resistance method, does not exceed fifty degrees centigrade after a ten hours' run at full load, the transformer may be passed as satisfactory in this respect.

In connection with oil insulation it must be remembered that its efficiency as an insulating medium is impaired by discharges in the oil. One of the foremost claims made in behalf of oil insulation is that it will flow in and fill up a rupture in the insulation of the coils. Every electric discharge that takes place through the oil, however, disintegrates and breaks up the normal structure of the oil, and causes carbon and other conducting compounds to form. These will rapidly multiply if the discharges are at all frequent, and will destroy the insulating properties of the oil. As a case in point, and I presume you may know of other similar instances, I want to call your attention to a very good example of what good practice *versus* bad practice will accomplish.

There is a city in the West in which the conditions under which electricity is supplied for incandescent lighting are somewhat unusual. There are two companies interested in the business, and both employ the alternating-current converter system of distribution. The plant that is operated by the older company was installed about six years ago, and its equipment has grown slowly from year to year as business expanded. Its development has followed the waves of evolution modifying electric-lighting practice within this period with a lag factor approximating ninety degrees. The plant has some strictly modern machinery, but much of the line equipment is old. A number of its transformers have been burnt out on account of defective insulation, some have been burnt out by lightning and some have shown their inefficiency by getting so hot when switched in on an all-day schedule, under light load, that the "oil used to insulate them boiled up and over, and ran down the outsides of the cases."

It is needless to say that in the latter type of transformer the hysteretic losses were considerable; the transformers were, however, manufactured by a firm of high commercial standing.

The lines of the old company are not protected by lightning arresters except where they enter the station, and the secondaries are not grounded.

The new company has been in operation two years, and its plant is thoroughly up to date and highly efficient. Oil-insulated transformers of from eighty to 200-light capacity are used, and are kept in continuous service. The transformers are of modern design and stand an insulation test of 7,000 volts, without oil. The lines of the new company run over those of the old company, and are protected about every 1,500 feet by lightning arresters. None of the secondaries of these transformers are, however, grounded, and magnetic shields are not used. The new company has never experienced any trouble from burnouts of any kind, although its lines are very much exposed. In a very violent electric storm that occurred some time since, in which the service of the old company suffered in consequence of transformer burnouts, the service of the new company was not interfered with in any way, although lightning struck its lines several times.

There has been a great deal of interest expressed recently in the effort to formulate a definite set of specifications covering the construction and insulation of transformers, with the end in view of decreasing the fire hazard and supplying the necessary protection from loss of life and property to both the producer and consumer of electrical energy. In a letter that I have lately received from a gentleman who is much interested in the success of this project, he says that, after corresponding with a number of makers, engineers and lighting companies, to obtain suggestions as to the remedies for the troubles arising from crosses, lightning, insulation, breakdowns, etc., the results were very unsatisfactory, as there seemed to be a vast difference of opinion.

I have read a great many articles for and against the use of earthing devices, grounded shields and grounded secondaries, but I am yet to be convinced that the prominent American practice of high-insulation resistance to a disruptive discharge and a plentiful use of well-grounded short air-gap lightning arresters, does not give a sufficiently good protection. As I have already remarked, the number of modern transformers that are reported as burning out is relatively very small. By far the greater portion of the troubles arise from crosses between the high- and the low-potential circuits, and in such cases the loss must be attributed to faulty installation and not to any imperfection in the transformer.

An oil-insulated transformer for use on 2,500-volt primary circuits, or less, having a maximum temperature at full load not exceeding sixty-five degrees centigrade and designed to stand an insulation test without oil of 7,500 volts for five minutes, and a prolonged test of 10,000 volts with oil, will be in slight danger from lightning discharges if protected within a distance of 500 feet by a properly installed lightning arrester.

A transformer should also be able to stand a double primary potential test for five minutes, and the insulation test should be made between the coils and between each coil and the core.

In the case of transformers to be used exclusively on very high-voltage circuits, these considerations do not apply; nor should this paper be considered as dealing with this class of alternating apparatus, which has come to form a department by itself.

In considering the economy of transformers, the problem before us is not so much a discussion of their efficiency as converters of electrical energy, as it is a discussion of this efficiency in connection with the numerous extraneous causes that tend to make the transformer a menace to life and property.

To my mind, a great deal would be gained if an understanding could be brought about between the makers and purchasers of transformers that would result in a uniform practice in the several departments of transformer design. The manufacturers would work to better advantage by having definite specifications to work to, and the way would be open for a bonus or forfeit in equitable proportion to an excess of or shortage in the economy of the product. The fad at present tends toward over-protection. It is bad practice to run to extremes in any department of engineering, and too much protection may turn out to be just as costly as too little.

The President: Gentlemen, you have heard this very interesting paper, and it is before you for discussion. I beg, however, at this time to announce the committee to nominate officers and members of the executive committee for the ensuing year. I will appoint as a nominating committee the following gentlemen: A. M. Robertson, Minneapolis, Minnesota; James R. Dee, Houghton, Michigan; James I. Ayer, Boston, Massachussets.

DISCUSSION

THE PRESIDENT: We will now discuss the paper on transformer economy.

MR. LAYMAN: There has been a great deal of criticism of the transformer, but the reason for that cannot be traced directly to the manufacturer. The manufacturer has developed the transformer, to a large extent, without aid from the central-station man. The central-station man has not until recently made tests of the transformer. He has accepted it as a switching device, or its equivalent, and has not endeavored to protect himself by securing the best apparatus. But of late the competition between manufacturers has developed the fact that there is a great deal of difference in transformers, and, now that the subject is being very actively discussed, I think that the central-station man should make a special object of going into it deeply, and thereby assisting the manufacturer in developing the apparatus to its highest point.

The transformer can be a good piece of apparatus, or it can be a poor one. It can be built to conform to definite specifications; and, as representative of a manufacturer, I would say that the modern manufacturer would be pleased to have a uniform set of specifications by which to design the apparatus. There are various standards for comparing transformers; there are various bases for all-day efficiencies; various tests for heating effect; various insulation tests, and many variations of tests that make it impossible for the manufacturer, as well as for the central-station man in general, to know just what is required of the transformer. I should like to have the discussion taken up along some of these lines, and if any points of interest arise that can be answered by the manufacturer, I shall be glad to go into the discussion later.

MR. THAYER: In the manufacture of transformers and in the specifications sent out as to the performance of transformers, I have never seen any difference made in transformers suitable for operating lamps at different hours in the day. We have now in the country a class of central stations that operate six hours a day; there is another class that operate twelve hours; and there is still another class, which is the growing class, that operate twenty-four hours. It is evident that it would be wise in the six-hour plant to increase the iron losses at the expense of regulation, but I have never as yet seen any transformer manufacturer that makes any distinction in the transformers for these different classes of stations; at least, it does not appear in their published catalogues or reports. He may have different types of transformers that will conform to these various uses, but it seems to me to be a point that has never excited the interest of the transformer man, and, in fact, the owners of the short-hour stations usually look at the first cost of the transformer as the most important matter connected with it.

There is another thing, and that is the protection of the transformer from lightning. In a paper read some time ago by Mr. Wurts, of the Westinghouse company, he likened the condition of affairs on electrical lines when the lightning strikes the circuit to that of the ripples of water in a tub when a stone has been thrown into it. It means that the highest rise of potential is not necessarily near the point at which the stroke takes place. It may run off half a mile or a mile before the conditions are just right for a piling up of the potential to extreme high limits. That would seem to indicate that it would not be the best practice possible to place transformers along the line at convenient intervals, but, rather, to place them at the points where the lightning is more likely to strike. In the case of my own plant, I have never, thus far, lost a modern transformer by lightning. Our losses have invariably been on the older types of transformers, and the discharge has in many cases entered the line, and not only passed several lightning arresters, but has gone to the end of some branch of the line and there burned out some of the old-type transformers, so in that case the near-by lightning arresters did not protect, although they were in good repair, with an excellent ground.

MR. FAKES: I would inquire if the lightning would not be just as powerful running on the secondary as running on the primary, and, therefore, the transformer acting as a booster? I have known of instances of that kind, and it simply tore four or five transformers all to pieces.

MR. WURTS: The subject of lightning arresters being up for consideration, I should be glad to say a few words. I do not recall the paper referred to by Mr. Thayer, in which he says I have compared the surging of static discharges to the rippling of water. I have frequently likened the surging of static discharges in overhead wires to the surging of water in a trough. This illustration is, I believe, original with Professor Lodge, and shows in a very graphic way what actually happens in a wire. The theory of surging static charges in a wire is attractive and interesting; there are, nevertheless, many of our central-station men that question whether there really is any such thing as a surging of the static charge. It is very true that too much importance should not be attached to theories, but in this case the theory has been adopted since the facts have been developed, and a large number of important facts have been developed which clearly point to the correctness of the theory. In the present instance, the theory, as well as the mechanical analogue referred to, serve as a happy and convenient means for showing central-station men just what happens in their wires during thunder-storms. I think all of us will admit that these discharges occur at one point or another regardless of any law with which we are familiar. I have personally conducted a great many experiments to accumulate data on this particular point. For instance, I have connected non-arcing lightning arresters at frequent intervals over an aerial line, and in series with each lightning arrester have placed a small piece of tissue paper, which, being punctured, gave a register of the discharge. These papers were collected after each storm, and a record was kept of the points from which the discharges occurred; but I have not, as yet, discovered that these discharges follow any law whatever; nor would it be consistent with the theory that has been developed that they should follow any law, for the points at which discharges occur are dependent upon conditions that must necessarily change with every lightning flash. In one instance I connected a single lightning arrester to three lead wires running to three different points on the main line In each of the three lead wires I placed a small spark gap containing a slip of paper. After the thunder-storms the papers were examined and usually all three were found punctured, thereby showing that the path selected by the discharge was not the "shortest and easiest path to earth," but one that was dependent upon external conditions.

The name "short gap" is somewhat modern, and has been applied to a lightning arrester that has for its path between line and ground a so-called "low resistance" in series with a single-spark gap. The natural inference would be that the lightning arrester having one air gap is a short-gap lightning arrester in comparison with a lightning arrester that has three gaps between line and ground. When the general requirements for installing lightning arresters are such as to call for nothing smaller than a number six copper wire between line and ground, soldered joints and a good ground connection, it seems very strange that one should deliberately insert in the lightning arrester itself a resistance that is not a comparatively low resistance, but an enormous resistance compared with the rest of the connections.

Furthermore, I will ask a question and will endeavor to answer it myself; it is this: How shall we measure the resistance of a lightning arrester? By what unit shall the resistance of a lightning arrester be measured? What kind of a scale shall we refer to in calling one a low-resistance lightning arrester and another a high-resistance lightning arrester? I have frequently seen the statement that a lightning arrester should break down with a low electromotive force, and that the lightning arrester that breaks down with the lowest electromotive force is the one that will be the most effective in service. I take exception to any such statements as these. A lightning arrester, as a path for lightning discharges, has nothing whatever to do with dynamo current or dynamo electromotive force. Take, for example, the short-gap lightning arrester referred to, which consists of a resistance of sixty ohms connected in series with a single spark gap. The dynamo electromotive force that will start an arc, that is, that will break down the spark gap, is exactly the same as if there were a thousand or a million ohms connected in series with the spark gap. If, then, the breaking-down electromotive force is a proper test to apply to a lightning arrester, it would follow that an ohmic resistance, no matter how high, connected in series with a spark gap would not alter the effectiveness of the lightning arrester in performing its proper functions during thunder storms, which supposition is manifestly absurd. It follows, therefore, that the breaking-down electromotive force of a lightning arrester has nothing whatever to do with determining the effectiveness of any such device as a path for disruptive discharges. It seems to me that the only fair way to measure the resistance of a lightning arrester is to measure in some way the *resistance that a given lightning arrester may offer to the passage of disruptive discharges;* for the function of the lightning arrester is to offer a path of low resistance to the passage of such discharges.

How may the resistance that a lightning arrester offers to the passage of disruptive discharges be measured? The method that I have adopted, and which seems to me entirely satisfactory, is to connect in shunt to the lightning arrester a variable spark gap, and then, while disruptive discharges are passing through these two parallel paths, one of them being the lightning arrester and the other the variable spark gap, the latter is adjusted until the disruptive discharge shall pass indifferently through the arrester or through the shunt gap. When this condition is reached, the two paths may be said to be balanced, and one is a measure of the other. The length of the shunt gap is a measure of the resistance which that particular lightning arrester offers to the passage of disruptive discharges. If a second lightning arrester be substituted for the first and the above measurements repeated, the resulting shunt gap will again be a measure of the resistance offered by the second lightning arrester to the passage of disruptive discharges.

In making comparative measurements of the above kind between the lightning arrester referred to as having a spark gap and a resistance in series with the spark gap and that of the lightning arrester having three gaps in series, I have found that the former arrester has just three times the resistance offered by the latter to the passage of disruptive discharges; and these measurements were further verified by finding that when three of the latter arresters connected in series were further connected in shunt to a single short-gap lightning arrester, the balance was established; thereby proving in a somewhat different way that the resistance of a single short-gap lightning arrester was three times that of the arrester having three gaps in series.

The question now arises as to why the resistances are as I have shown them to be. I have made a great many measurements to determine this, and am satisfied that the reason is due to the presence of the ohmic resistance in the short-gap lightning arrester. The path of the lightning arrester that has three gaps without ohmic resistance, I should describe as a "free-path" lightning arrester; whereas a lightning arrester having ohmic resistance in series with the spark gap I should describe as a "restricted path" lightning arrester; and in describing the difference between these two paths, it must be accepted that the disruptive discharges are oscillatory in character. Bearing this in mind, then, I should liken the passage of the discharge through the free-path arrester as something similar to the passage back and forth of a bullet through a pane of glass. The glass being once broken by the first passage of the bullet, the passage is free for further oscillation. The passage of an oscillatory discharge through a restrictive path, I should liken to the passage to and fro of a comparatively large body of water through a very small hole; nothing is broken, the hole is not enlarged, therefore the resistance that it offers is present for each to-and-fro motion of the water.

Mr. Wagner: I should like to take this opportunity to endeavor to correct an assumption that for several years has been made in considering the average load on transformers, and especially the so-called all-day efficiency of transformers. The assumption made by Professor Goldsborough, which has been made by many other writers on transformers, of five hours' average load in the twenty-four, is never realized in practice; I mean average practice. The electric-light stations having the largest station load rarely exceed twenty per cent of this maximum all the year round. The maximum station load rarely exceeds fifty per cent of the connected lamp load. With the use of transformers for house-to-house distribution it is necessary to have the transformer capacity practically equal to the number of lamps connected. Therefore, with the maximum station output the transformers will be loaded only one-half of their rated capacity; and if the average station ouput is twenty per cent of the maximum, you will have an average load on the transformers of twenty per cent of fifty per cent, or only ten per cent of their rated capacity. Applying that to obtaining the equivalent number of hours that the transformer should be operated at full load to show the same efficiency, we find that it would be ten per cent of twenty-four hours operated at full load, or 2.4 hours, in place of five hours. This average load would somewhat affect Professor Goldsborough's figures, and while it would show in general that transformers have a lower average efficiency, it would show more strikingly that the modern transformers are greatly improved over the old transformers.

I would also say that in estimating the cost of the transformer load to the central station, it would seem more fair to take simply the cost of coal per kilowatt-hour into consideration, as an increased loss in the transformers would not increase any of the labor items or any of the fixed charges in connection with station operation; but as it only increases the coal consumption, that would be the proper figure to consider when calculating the cost of these losses to the central station. The average cost per kilowatt-hour for coal has been shown by statistics to be somewhere around three-fourths of one cent per kilowatt-hour in some few stations, and it is often over one cent; but the average seems to be about three-fourths of a cent, and that might be a fairer figure to consider in the cost of these losses than the figure of two cents per kilowatt-hour, which Professor Goldsborough has assumed.

Mr. Davis: What is considered to be the present rate of depreciation of the most modern type of converter? How often must a transformer be renewed?

Mr. Wagner: That is a pretty hard question to answer, as it depends so much on the conditions of operation and on the locality. In a great many, perhaps the majority, of alternating-current stations at present in operation in this country, the old transformers first purchased with the original installations are still working. The first stations were installed in the early part of 1887, and some in the latter part of 1886. A large proportion of those transformers are still in operation, showing that their life has not ended. A great many, however, have been destroyed by lightning and by the causes to which Professor Goldsborough has called our attention, and the number of transformers destroyed by lightning may in many cases be a large percentage of the transformers installed during the last ten years. It depends on the conditions of the lines and the methods of protection of the lines, so that there is no reliable basis for estimating the life of transformers. It must be understood that the transformers made to-day will have a much longer life than the transformers made ten years ago when the industry was in its infancy,—the alternating-current industry—so that is a very difficult question to answer. The depreciation of a modern transformer would not be greater than ten per cent; I imagine it would be less than that; at least, not so great as the depreciation of the generating apparatus, which is usually taken at about ten per cent.

Mr. Matlack: Our experience with the lightning arrester has been that we receive at least as many discharges on motors comparatively isolated on top floors of buildings, where there is no possibility of discharging to the ground, as we do on motors in the basement. The discharge is between the wires, and not necessarily to the ground. Most of our trouble has been with machines perfectly insulated from the ground. There are no indications of discharge to the ground.

MR. WALBANK: I should like to ask the relative life of the transformers cooled by oil and cooled by an air blast.

PROFESSOR GOLDSBOROUGH: I am not entirely prepared to answer the question and give definite information. Where good oil is used, the advantage is largely in favor of oil-insulated transformers. There is an opportunity for the unoiled transformer to deteriorate with a rapidity that is far in excess of the rate of deterioration of a transformer insulated with good oil; but if the oil contains impurities, if it is of low quality and will not stand a high insulation test, it may happen that the oil will be more detrimental than beneficial. There are many things that enter into this problem, and I should say that it should be a matter of standard rating by test; we could then compare transformers made by different companies.

A question has been asked regarding the time of scrapping. It is hard to define a limit. I make no effort to make matters appear worse in my paper than they are; I simply wish to give you a fair statement of things as they exist to-day, an idea of what you are likely to meet with, and not a discussion of a condition that existed last year or the year before. We have had transformers in our laboratory in which the core losses ran up so fast with use that the transformers would better have been thrown away before being installed. This is no longer the case, and we are getting better transformers. We have had modern transformers in which the iron loss has increased twenty per cent in a year. Should we scrap such a transformer at the end of the year? It depends on what power is worth, and it is a matter of dollars and cents that should be figured by each central-station manager with regard to his own plant. If it costs one cent per kilowatt-hour to develop power and it is sold cheaply, the aging loss is not so important; if the power is expensive and you are selling it at a high rate, then the amount of power that you can sell is of moment. If you have a transformer with high core losses, it is simply using so much of the available energy of your station, and you have so much less to sell. You must look at it from the standpoint of the amount of coal that it represents, and also from the standpoint of the amount of reduction it introduces into the total available output of the plant, and the total income of the plant. It should be made a matter of very careful study. You will hardly find two plants in which the conditions will be the same.

As regards the transformers manufactured to-day, I should say that, in general, with the transformers on the market the aging loss for a year will not be over ten per cent, and in many cases not so much as that. I am rather inclined to doubt the claim that it "will be less than one or two per cent." I have not had the pleasure of making tests on transformers with so low a rate of aging.

MR. HUNTLEY: In the operation of these tests, have you discovered any tendency of the transformers to separate the oil?

PROFESSOR GOLDSBOROUGH: Carbonization of oil takes place wherever a disruptive discharge occurs. It is possible that there is a tendency for a separation to take place in the oil in case it contains any appreciable amount of moisture; that is, if you place oil under heavy electrostatic stress, any moisture or foreign matter in the oil may serve to oxidize some of the molecules of the oil. This introduces a conducting matter at a weak point. The consequence of this is that it will act to start a disturbance in your transformer. If there is a weak point in the insulation or material of any kind, a strain tends to aggravate that weak point. I have not had an opportunity of testing under very high voltages, so that I am not prepared to make any decided statement covering this point. My experience has been that carbonization of the oil occurs for every discharge that takes place, and there is probably a certain amount of it that occurs before the discharge takes place.

MR. HUNTLEY: You rather favor an air-cooling transformer, then, than an oil-cooling transformer?

PROFESSOR GOLDSBOROUGH: You mean the insulation of the transformer by forcing through it large quantities of dry air?

MR. HUNTLEY: Yes, sir.

PROFESSOR GOLDSBOROUGH: I believe that *perfectly dry* pure air is as good an insulator as we can find, and the next best thing is high-grade oil, free from injurious matter.

MR. WAGNER: A company operating several plants in the West, and having a great deal of experience with high voltages—that is the Telluride Transmission Company—has used oil altogether for the insulation of its transformers. It made an extended experiment on this line. I think Mr. Layman has some information about the results obtained by this company with oil and the effects of carbonization. There is one other question that is of considerable importance in the use of oil, and that is that it absorbs moisture. If you let it stand for a considerable time exposed to moist air or air at the ordinary temperature, and the transformers are operated at intervals only, and not kept continually in circuit so that the oil is kept at a fairly high temperature, the oil will absorb a small amount of moisture, and it is likely to give some trouble from this cause. In many cases where transformers have been used for intermittent service, it has been found necessary at frequent intervals, according to the frequency with which the transformers go out of service, to draw off the oil and heat it to a high temperature, say 300 degrees, in order to expel the moisture, or replace it with other oil. So far as the carbonization of the oil is concerned, Mr. Layman can give you some definite information about that. Mr. Walbank asked the question: Which is the best means of cooling transformers—an air blast or oil? As Professor Goldsborough has said, dry air is as good an insulator as can be found; but air blown through the interstices of coils of transformers by blowers, as attempted in many cases, is likely to contain much dust, and that dust accumulates in the transformers as it is drawn in by the currents of air, and must be deposited when the velocity of the air decreases. I should imagine that the dust would in time seriously affect the insulation, in the way of bridging across the air gaps that are provided to prevent the high potential from jumping across.

MR. LAYMAN: Reference has been made to the Telluride Transmission Company. I have no specific data on their oil, and can only repeat statements made to me by their engineers. They make it a practice, as we do with all our oil, of carefully placing it in condition for service. This oil, as received, may not be in condition for safe use. They carefully eliminate all particles of dust, or anything of that character, and also eliminate all moisture. They find, as we do, that there is a very slow but gradual improvement in the quality of the oil with heating. So far as the carbonization of the oil is concerned, there is no carbonization. In transformers that I have been watching for two years, I made tests upon the oil when it was placed in the transformer cases and have also made numerous tests since. The oil when introduced into the transformers would stand a puncture pressure between points of 8,000 volts for a space of one-eighth inch. At the end of three months, I very carefully took samples of the same oil from the bottom of the cases (the general impression being that if there is any moisture in the oil, or any heavy impurity, it will go to the bottom), and found that I could not, with 10,000 volts, break down that oil with a space between the points of one-thirty-second of an inch. We also made a chemical analysis, and our chemist found no trace of carbonization. There had been some change in color, but, so far as he could determine, there had been nothing to lower its value for insulating purposes. I will say, however, that these cases are carefully closed so as to exclude dirt, and that there is no opportunity for moisture to settle in them, because the transformers are continually in service for twenty-four hours per day, and a large part of the time heavily loaded, so that the oil is not allowed to cool. In fact, these transformers were designed with a water jacket, to take care of excessive runs at full loads, and, by means of indicating thermometers, they regulate the flow of the water. They operate continuously at practically 200 degrees, so that if there had been any carbonization taking place at that temperature, it would have manifested itself in two years' time. I have tests on oil of another installation that has been running a year and a half, and the same character of results was secured there.

The fact of the matter is that if a transformer under ordinary conditions is allowed some ventilating space above the oil, and no dirt gets in, the oil will improve in quality until there is a complete elimination of moisture. I think I agree with Professor Goldsborough in his statement that there cannot be too much care shown in the selection of oil. The purchaser of the transformer has not the facilities for protecting himself in selecting oil, and therefore it is the practice of the company that I represent not to allow oil that we do not furnish to be used in our transformers; not because the purchaser cannot procure the oil we use, but for the reason that he cannot protect himself as to the quality in the manner in which we can protect him.

I was asked by Professor Goldsborough last night if I thought it advisable for a central-station man to test his own transformers? He said it had been his experience in his laboratory that his students, who received instruction in the process of making tests and knew the instruments used, could not make reliable tests except under his immediate direction, and that he could not place any dependence on results except when he saw the tests made.

The position I take is that the preliminary tests of a central-station man would not be satisfactory; but any central station that has the proper instruments can, after a few trials, quickly make all the tests necessary to indicate to his complete satisfaction what the transformer will do and what is its relative merit. I think that since this association is given to the education of its members, as well as their social profit, one direction in which it might lend a great deal of assistance would be, not only formulating careful specifications for transformers, but also in formulating tests for transformers, and in issuing these tests in such shape that they could be taken hold of by any central-station man and used satisfactorily by him.

MR. HUNTLEY: Do you regard the use of oil as at all dangerous in the event of a burnout in your transformer?

MR. LAYMAN: The characteristics of the oil have much to do with that. There are a number of grades of oil used, in which the fire test of some is as low as 300 degrees and of others 500 degrees. The danger from fire with the transformer case filled with oil is very slight.

PROFESSOR GOLDSBOROUGH: I do not think you will often run across instances in which fire has resulted from the use of oil. It is a fact, however, that this may occur, and will occur, under certain conditions. There was a case that came under my observation some time ago. It was the case of an old transformer that had not originally been insulated with oil, but which, in the effort to improve it, had been filled with oil. The iron loss of the transformer was so high at full load that a great deal of heat was generated, which caused the oil to expand and run over the case. In making some changes and trying to improve the condition of the transformer in one way or another, the attendants left the top off the transformer case, and when the oil cooled down the level of the oil fell below the windings. When the transformer was cut in again a short circuit occurred between the primary and secondary windings, as there was a weak place in the insulation and the flash set fire to the oil. That is the only instance of the kind that has come to my attention.

MR. LAYMAN: There was recently reported in the *Engineering News*, which is generally very reliable in the news that it prints, the fact that a transformer in process of construction by the company I represent had exploded and set fire to the oil and also to the factory.

The fact is that an entirely different situation existed. The transformer had been given a thorough test for load, and was being given a final insulation test. In making this test we followed our usual practice of gradually increasing the primary voltage above the normal. We were doing this as a final test, and there developed in the apparatus a defect in insulation and a strong arc resulted underneath the oil. The test was repeated a number of times, to locate the point of breakdown, while the oil was in the transformer. Then the oil was drawn off, and we began with a low pressure, endeavoring to produce the same jump without the oil, so that we could see its location. Finally, at a given pressure, a blaze resulted, and we located the point. The interesting fact was that we produced the arc a number of times under the oil without trouble, but had not been able to locate its position until after the oil had been drawn off.

THE PRESIDENT: There are no papers for the afternoon session, but a number of committee reports are to be presented. Before adjourning this session, I would urge you to be present this afternoon promptly at half-past two as there is a great deal of work to get through and we want to finish at a seasonable hour, in order that those wishing to catch the afternoon trains may do so.

Adjourned.

SIXTH SESSION

President Insull called the meeting to order at 2.55 p. m.

THE PRESIDENT: Has the committee on standard candle power of incandescent lamps any report to make?

MR. AYER: Mr. President, the committee, composed of Dr. Bell, Mr. Ferguson and myself, have had this matter in hand, but being so widely separated as we are, two members of the committee living in Boston and the other in Chicago, it is difficult for the members to get together. We have done some correspondence, and it has been necessary to carry on some experimental work. This has been done at the Boston Institute of Technology. Professor Puffer, of the engineering department, undertook to make a lot of determinations to enable us to get a basis for a set of specifications. We could not get the report of those investigations in time, but since my arrival here I have received a communication from Dr. Louis Bell that will give you a good idea of the work of the committee. I will present it as the report of the committee.

REPORT OF THE COMMITTEE ON STANDARD CANDLE POWER OF INCANDESCENT LAMPS

Gentlemen:

Your committee has been able to have tested in the most careful manner, through the courtesy of Prof. W. L. Puffer, of Boston, sixteen-candle-power incandescent lamps from eleven different makers. The lamps were obtained directly from the makers or their authorized agents, and were known to be for test.

These lamps were all sold for sixteen candle power, 110 volts, no watts specified, and may be fairly assumed to represent the product that would be shipped to consumers who did not desire the lamps for test; although one batch of lamps came with the bases marked to show the point to be turned toward the photometer screen.

On test, these lamps—thirty-three in all—averaged 14.1 mean horizontal candle power and about 11.7 mean spherical candle power. Only one batch of three averaged over sixteen horizontal candle power. One batch fell below eleven horizontal candle power and two below twelve horizontal candle power. Five makers fell below 14.5 horizontal candle power. The highest average of any batch was 16.99; the lowest, 10.82. The average consumption of energy was almost exactly four watts; the lowest, 3.78 watts per candle, and two batches ran over five watts. It should be noted that the voltage was determined by a Weston voltmeter freshly compared with Clark cells, and each lamp was run at its marked voltage (110 volts).

A separate series of tests showed that these lamps on the average gave their mean spherical candle power when measured under rotation, with their axes tilted forty-four degrees twenty-four minutes from the vertical toward the photometer, thus confirming closely your committee's estimate of forty-five degrees as a proper angle. The individual variations, however, were considerable, averaging several degrees.

A series of tests on proper speed of rotation showed that the best results were obtained with a speed of 200 to 250 revolutions per minute, and that the lamps would readily stand this speed.

Many of the lamps showed had spherical distribution, which seems to be quite needless, since it is merely a matter of properly proportioning the form of the filament.

Of an equal number of batches of thirty-two-candle-power lamps, only one batch averaged thirty-two horizontal candle power, the majority falling to twenty-six and twenty-eight candle power. The thirty-two-candle-power lamps averaged slightly greater efficiency, but were otherwise much like the sixteen-candle-power size.

From this investigation, the fact stands out that the incandescent lamp sold for sixteen candle power is, on the whole, a lamp giving considerably less than its rated candle power, even when new. Some of these lamps would probably show a temporary increase of candle power after, say, fifty hours' burning; but the committee has not extended the research in this direction as yet, and adheres to the opinion that initial candle power is the only practicable commercial test, and consequently any increase is simply regarded as a device for keeping the lamp a little longer from its inevitable decay.

From these and other data kindly furnished by manufacturers and obtained from various other reliable sources, your committee is convinced that the need of a uniform rating is even greater than it concluded in the preliminary report of last year, and that a rating test, in order to be effective, must involve measurement of candle power of lamps in more than one direction. Neither mean horizontal or mean spherical candle power, nor candle power in any one direction, will define a lamp well enough to insure adherence to the rating.

Your committee therefore recommends that incandescent lamps be required to conform both to a standard mean horizontal candle power and to a mean candle power when revolved with the axes tipped forty-five degrees, this representing the spherical distribution.

It recommends that the limits for the mean horizontal candle power be fifteen and 17.5 candle-power. Unless the minimum be as high as fifteen, there will certainly be found a tendency to produce lamps near the lower limit. The forty-five-degree candle power should be *at least eighty-five per cent of this minimum.* This is not an excessive requirement, and will tend to prevent working near the lower limit of horizontal candle power unless with a lamp very good in other respects.

Your committee has blocked out a standard form of photometer, a type of which it proposes to build, test and put at the disposal of the association with directions for proper use.

It suggests that testing be by sample, a lot of ten lamps being taken from each barrel. Of these, no lamp when run at its marked voltage shall show less then fifteen or more than 17.5 candle power (mean horizontal) when rotated at 200 to 250 revolutions per minute. And no lamp shall give, when thus rotated at forty-five degrees inclination, less than eighty-five per cent of the above minimum.

Your committee will make arrangements for standard lamps as indicated in the preliminary report, to go with the standard photometer.

Respectfully submitted,

Louis Bell, Chairman,
James I. Ayer,
Louis A. Ferguson.

THE PRESIDENT: I think it very desirable that the work of this committee should be continued in a little different form. I think the interests of the association would be served by the personality of the committee being changed, as Dr. Bell, who has done some very valuable work for us, seldom attends our meetings now; and I would suggest, in taking action on this matter, that a motion be made that a committee of three be appointed by the chair to take up the question, not only of the standard candle power of incandescent lamps, but standard specifications for incandescent lamps. It will be within the recollection of some of you that I referred to this matter in my opening remarks. I am sure, from my experience in another association, that the interests of the users of incandescent lamps can be well served by the adoption of standard specifications that will compel the manufacturers to specify what they supply us with.

MR. AYER: I want to say in behalf of Dr. Bell that he is in the employ of the government, in the engineering department. He intended to attend this meeting, but could not do so. I see no reason why the recommendation of the committee should not be adopted. I ask that that action be taken; that the report be adopted.

MR. BURLEIGH: I make a motion that the report of the committee be adopted and the committee discharged, and some other committee be continued in its work, as outlined by the president.

Motion put and carried.

THE PRESIDENT: I appoint as the committee, Mr. James I. Ayer, of Boston, chairman; Louis A. Ferguson, of Chicago, and Calvin W. Rice, of Brooklyn.

REPORT OF COMMITTEE ON LEGISLATION CONCERNING THEFT OF CURRENT

THE PRESIDENT: We will now take up the report of the committee on legislation concerning theft of current.

MR. AYER: I was appointed chairman of the committee, Mr. President, and Judge Armstrong was to act on it merely by courtesy. I want to state the case and put the trouble and blame where they belong; I want to hit the judge and he will hit me back. This thing seemed to be of considerable importance, and when the committee was appointed, soon after the convention adjourned last year, the chairman sent out letters through the medium of the secretary to members of the association and central-station people generally in all the states of the Union. We got replies from thirty-seven of the states, all expressing much interest in the idea of establishing a uniform law, which should be made as strong as possible, to cover the case. Mr. Voorhees, who is now acting governor of the state of New Jersey, was on the committee, and when the data had been put together and referred to the legal end of the committee, — Messrs. Armstrong and Voorhees — Mr. Voorhees was compelled to decline to serve, because of having been appointed governor. The matter has remained in that condition.

MR. ARMSTRONG: I suppose it is not necessary for me to say, because that has appeared to you through the chairman of the committee himself, that he has absolutely failed on the first principles of the recognition of the duties of the chairmanship of a committee. I never knew that the other members of the committee had any province at all, except to add respectability to the committee. I have always understood that it was intended that the chairman of a committee should do all the work; so, while I did as a mere matter of form receive a letter from Mr. Ayer, in which he told me, what I already knew, that Governor Voorhees, who was president of our senate—you know we have had to do a good deal for the United States of America lately; we have furnished a vice-president, an attorney-general, etc., and when Griggs became attorney-general, Voorhees became governor—I presumed that this letter from Ayer was an ordinary courtesy, and I did not know that he wanted anything from me. He did send me, however, a compilation of laws. I have seen some curious things; but if these laws can be printed as an appendix to our proceedings here, and you can see how many different laws can be made on one subject, I have no doubt that you will be interested. The best, it is needless to say, is that passed by the state of New Jersey. It is the simplest of all of them, and will, I think, fully answer the purpose in any state. It was absolutely impossible, taking up a number of them,—speaking seriously—to undertake to make a composite that would answer any purpose. I understand that we have had no prosecutions in our state, and have had no difficulty about it. I do not see why a simple law, such as has been adopted by our legislature, providing that any unauthorized attachment made to the conductors, wires, or any other property of an electric light or power company, shall be a misdemeanor and punishable with a reasonable punishment, will not suit the purpose. I think it is the best law that can possibly be suggested. I do not see that we ourselves can go to any such length as to recommend any special enactment; and I would recommend seriously that what Mr. Ayer has collected should be printed as an appendix to the report of the proceedings of this convention, and in that way it may be useful to members of the association. I would, therefore, Mr. Ayer having failed to do so, report to the convention that we deem it inexpedient to recommend any special law, and that the laws collected by the committee be taken as its report.

THE PRESIDENT: It would appear to me that this is an important subject. We all suffer from theft of current, and I think our interests would be better conserved if we should refer the subject back to the committee, probably making Judge Armstrong the chairman, and filling the vacancy of Mr. Voorhees; and I think if a resolution were made to that effect——

MR. AYER: Mr. President, I make that as a motion.

MR. ATKINSON: I did not know that this subject was coming up to-day or I should have had with me a copy of the law passed at the last session of the legislature in Georgia, which we think is simple and covers the ground. It is not over twenty or thirty lines, and makes the penalty for stealing electric current the same as for any other similar misdemeanor. It is a very simple law, but it fully covers the ground. I merely rise to say that I shall be glad to furnish a copy of this law to the committee.

Mr. Ayer's motion was put and carried.

THE PRESIDENT: I will appoint as the committee Messrs. E. A. Armstrong, Camden, Chairman; James I. Ayer, Boston, and A. W. Field, Columbus, Ohio

THE PRESIDENT: Has the committee on amendments to freight classification any report to make?

MR. AYER: That committee desires the subject to be carried over for another year, for obvious reasons.

THE PRESIDENT: That will be granted. In my opening remarks I drew attention to the matter of standard specifications for the manufacture of electrical apparatus. I think it is important that we should have a committee on that subject. It is so important a subject that I think it would be better that it should be left to my successor to select that committee. I shall be glad if some one will make a motion that a committee of five on standard specifications for electrical apparatus be appointed by the incoming president, with instructions to co-operate with other technical bodies and electrical apparatus manufacturers, in order to arrive at some basis of operation on the subject.

MR. HUNTLEY: I make such a motion.

Mr Huntley's motion was put and carried.

MR. HUNTLEY: Mr. President, I move that we go into executive session.

Carried.

EXECUTIVE SESSIONS

TUESDAY AFTERNOON, JUNE 7

THE PRESIDENT: Our real object in having an executive session is to discuss confidentially the subject presented by Mr. Dow and the gentlemen following him. Before that subject is taken up, however, there are one or two matters that ought to be considered.

MR. AYER: I desire to offer an amendment to the constitution. The present article regarding the holding of the meetings reads as follows:

"ARTICLE V. MEETINGS

"The annual meeting of this association shall be held in May or June in each year, at such places as the association shall determine, and on such dates as may be determined by the executive committee."

Having had much to do with the selection of the locations for the meetings during a number of years past, I realize, as many of the members do, how difficult it is to harmonize the location with the wishes of the membership. It is very natural that we should have a large number of members wanting the location east of the Alleghenies, because we have more members in that section. As a national association, it was felt to be desirable that we should come west as often as possible; but we cannot stay west. When we come west, we get a good attendance from a district within a radius of a few hundred miles; but the next year we must, naturally, go back to the East, and these men do not come, so they lose their interest by failing to keep up their attendance; they do not care to go to a distance of 500 or 1,000 miles. The suggestion that we now have to offer is to fix two definite places of meeting, which would harmonize the meetings and overcome the difficulty we have in getting permanent membership in the West as well as in the East; in other words, sticking to the character of the association and maintaining it as national. New York is very central for the coast cities and the territory east of Allegheny mountains; Chicago is very central for the West. There are many of us in Massachusetts and other eastern states who will come to Chicago, and many western men who will go east; but the people that we are most desirous of benefiting—that is, the small central stations—can not send their men these long distances, and it is suggested that we hold the meetings in Chicago and New York alternately, making these cities the permanent location, one year in one place, and the next year in the other. A man can then go every other year if he cannot attend every year, and in this way he will keep up his interest. Most managers can go three or four hundred miles and get away for three or four days; if he is a western man, he will come here, if he does not attend the eastern meetings. I do not think we should scatter about as we have been doing; we should settle upon some cities like Chicago, Cleveland and New York. Cleveland is convenient for many, but it did not answer the purpose so well as Chicago. I therefore move an amendment to the constitution to the effect that the meetings be held alternately in Chicago and New York.

THE PRESIDENT: The motion is open for discussion and vote, unless five members object to it.

Mr. Armstrong: I do not want to object, but why do we want to bind ourselves to that in the constitution? I probably like the idea, but why not leave it all to the executive committee, just as it has been left? If it is our sense that we meet in that way, there is no trouble. If it were hard and fast, and there should be some special circumstances and the executive committee should think we ought to have a meeting elsewhere, we should be limiting them in their action. There is nothing to prevent our deciding that we will go to New York next year and the year after that to Chicago. We have discussed this matter a good many times, and while I am entirely willing that the executive committee shall fix the month and the time in the month, I am also entirely willing that they shall also fix the place.

Mr. Ayer: That is the old story. The object in fixing the place is not to take it out of the hands of the executive committee, but more to fix in the minds of the members the fact that every second year the meeting will be held in New York or Chicago. It is to make it a permanent part of the institution that the organization has its dual home in Chicago and in New York. It will result in time in producing a much stronger organization. Left to the executive committee as in the past—this thing has been discussed in this way—local interests and personal appeals, and sometimes conditions arising where men do not care to oppose the interests of others, would result in the meeting being held at some odd point, which would prove to be undesirable. For instance, we elect a president, and he would like to have the convention in his town. That is a proper desire on his part, and there are times when the executive committee does not want to take issue with the president. If he thinks we ought to do it, the committee gives way, sometimes very much to the detriment of the association. These are the main reasons why we want to make this a fixed thing. If the argument for the amendment is not good, it is proper to vote down the motion; if it is good, I see no objection to having it hard and fast. We can take it out of the constitution if it proves to be a bad move; it can be rescinded or changed, as we propose to change the by-law that now exists. I believe that the association would derive a great deal of benefit from the adoption of the amendment.

MR. KECK: The time of the meetings would be important to members from the South; we could not come in the winter time. I come from Savannah, Georgia, and should not like to come in the winter.

MR. CARNES: Would there be any objection to leaving the limit to May or June, in the discretion of the executive committee.

MR. ARMSTRONG: I would make a suggestion to the chair. I am willing to compromise, I am sure; and I would move an amendment that the meetings be held in the month of May, June or July, alternately in Chicago and New York, unless otherwise ordered by the executive committee. That will leave open the possibility of making a change if it is necessary; and it may be very necessary. The executive committee is not usually influenced by the president to do this thing. I tried to influence them once, but there is a difference in presidents, of course. I once endeavored to have them meet at a place of my choosing, but did not succeed. The present president did succeed, but the executive committee was not pulled around at all; it was fair and square, and decided by a tie vote; the president settled it by voting for Chicago.

Mr. Coggshall: The month of July would be a bad month for Massachusetts men. We make up our reports at that time, and are under a penalty of many hundred dollars.

Mr. Keck: Make it May or June.

Mr. Weeks: Circumstances might arise under which we should desire to go south. I think that I would place no restrictions on the executive committee, but leave it with the committee to determine the place. I think the sense of the resolution is very good, that the meetings shall be held in one or two great centres.

The President: Are you supporting Judge Armstrong's amendment?

Mr. Weeks: I am not supporting anything in particular.

Mr. De Camp: I think Mr. Armstrong's amendment renders it unnecessary to take any action. It is already in the hands of the executive committee. Put it in the shape of a resolution, to get the sense of this present meeting as to the policy of establishing the two permanent places for a meeting.

The President: I have been trying during the past year to get western members into this association, and I have failed absolutely, and the reason is that the western people have an idea that the National Electric Light Association is purely an eastern body, and that its meetings, as a rule, are held in the East, and the exception is to come to Chicago, or, rather, to the West. If we want to be a national association and get full membership, we ought to take some action on the subject. As Mr. Ayer has said, the small companies cannot afford to send their men away east. They do not see any object in the West in belonging to an association whose meetings they cannot attend. If we want to increase our membership and get in a large number of small companies throughout the West, we shall have to take some action that will put us in a position to claim that our association meets in the West. I do not see any objection at all to Judge Armstrong's motion to amend. The constitution will be an expression of the policy of the organization; and if any special circumstances arise, the executive committee can make a change. If it is the avowed policy to meet in New York one year and in Chicago the next year, I doubt if the executive committee will change it except under extraordinary circumstances. I will ask Judge Armstrong to write out his amendment.

MR. ARMSTRONG: Mr. President, I have written out my amendment, and will now read it:

The annual meeting shall be held in May or June of each year, alternately in the cities of New York and Chicago, unless otherwise directed by the executive committee, and on such dates as the executive committee shall determine.

Mr. Wagner seconded Mr. Armstrong's amendment.

The president put the amendment to vote, and it was adopted.

THE PRESIDENT: There is a resolution in the minutes of this association under which the members of the executive committee have a right to claim the payment of their expenses in attending meetings of the committee. I think that any gentleman who accepts the position—I know I can speak for those on the committee at the present time—any gentleman that accepts the position of member of the executive committee should either be willing himself to pay his expenses or his company should pay them, as the meetings of the committee are in the interests of the members. I wanted to call a meeting of the executive committee this year and got a waiver of each claim from each member before calling the meeting, in preference to putting the association into the hands of a receiver after calling it. I wish that some member would move that the members of the executive committee pay their own expenses when attending a meeting of the committee.

Mr. Walbank: Mr. President, I move that hereafter the members of the executive committee pay their own expenses when attending meetings of the committee.

Mr. Scovil: It is very important that the members of the executive committee should attend the meetings, and this motion may have the effect of deterring them from doing so.

Mr. Atkinson: The meetings of the executive committee are important, and it is pretty hard to saddle the expense on the companies. The work is in the interest of us all, and I for one am heartily willing to bear my portion of the expense of the meeting of the executive committee.

Mr. Armstrong: They have not usually been paid.

The President: Since this resolution was put in our records the association has become a one-man organization from convention to convention. This is not right; the association is too important; the interests involved are too great.

Mr. Atkinson: I move as an amendment that the expenses of the necessary meetings of the executive committee be assessed on the membership, and that the finance committee take the matter in charge and see that it is done.

MR. KECK: How much money should we have to raise to pay for a meeting of the committee?

THE PRESIDENT: I have not figured that out; but I can tell you how much it would take to pay for my expenses as president during the past year, part of which I have paid and part of which my company paid.

MR. BURLEIGH: At no executive committee I ever attended was there anything paid.

MR. ATKINSON: It ought to be paid. How many meetings are held during the year?

THE PRESIDENT: During the last year or two we have not had any meetings.

MR. AYER: We did not have any during my administration.

THE PRESIDENT: I asked Mr. Nicholls why he did not call any meeting, and he told me that was the reason, and he did not care to ask the committee to meet.

MR. WAGNER: I think the companies represented on the executive committee get certain advantages from that representation that the other companies do not get, and they should be willing to bear that item of expense. Almost every company is represented in turn, and sooner or later it would be spread throughout the association. There is no other way to provide for this expense.

MR. CARNES: It would be better not to have it embodied in the by-laws that you cannot afford to have a meeting of the executive committee because you have no funds. It should be understood that members who accept appointment on the executive committee should accept it conditionally upon bearing their own expenses, or should decline the election.

MR. ATKINSON: It seems to me that the expenses, divided among the membership, would be a small item. I think the expenses of the committee ought to be paid. I am not familiar with the advantages that accrue from membership on the committee, but it would seem to me that the only advantage is the loss of time and money as well. It would be hard to get suitable men on the executive committee, and under such circumstances it would be difficult to get meetings of the committee, and the committee would amount to very little. The question as to whether the executive committee is worth having seems to be involved; and it seems to me that the expense, divided up, would be a merely nominal matter, and nobody could object if they were in favor of the association and its work; and I would urge my motion.

MR. SCOVIL: I would second Mr. Atkinson's motion. This is a national association, and I think there ought to be on the executive committee men that represent the small companies. It is easy enough to get the representation of the larger companies, who can stand the expense; the men representing the larger companies have salaries sufficiently large for them to pay their own expenses. This is a national association, and there are many managers that do not get a large enough salary to be able to afford to pay their own expenses.

THE PRESIDENT: You cannot assess your members. The basis of membership is a certain amount per year as dues; you have not the right to assess your members. If those gentlemen that have urged the desirability of such a course have tried to raise money for special work in connection with the electric-lighting business, and have succeeded, by collecting it from various companies, I wish they would let me know how to do it; because I am out $2,500 at this moment on the work I am going to talk about.

MR. WEEKS: You are right, Mr. President, in regard to the impracticability of assessing members for this expense. During my administration of the affairs of the association, we never had an officer or member of the executive committee (except, of course, the secretary) whose expenses were paid. We never heard of the question being raised by anybody, or any claim being made upon the association on that account. So far as I am concerned, I know I am not out so much as the present president, but I spent a good many hundred dollars for work purely for the benefit of the association; but, fortunately, during my term as president, I found enough of the active members of this association that were patriotic enough, if I may so speak, to go down into their pockets to the extent of two or three hundred dollars. There were about fifteen members that contributed. This was done, and no record made of it, and no claim was ever made upon the association for re-imbursement of that sum. I am not clear what the necessity is for this action. Why need we pass any resolution; why not go on as we have done, paying our own expenses?

THE PRESIDENT: Mr. Atkinson's motion, if carried, would mean that this association would be responsible for the expenses of the executive committee in attending meetings of the committee. Any member of the executive committee would have a legal claim upon the association in connection with his expenses. I will now put the question on Mr. Atkinson's amendment.

The amendment was put to vote and lost.

THE PRESIDENT: We will now take a vote on Mr. Walbank's motion,—that the present resolution on the minutes of the association, that the expenses of the executive committee be paid by the association, be canceled, and in future the executive committee shall pay their own expenses.

This motion was put to vote and carried.

THURSDAY AFTERNOON, JUNE 9

THE PRESIDENT: The report of the secretary and treasurer will now be presented.

The secretary presented the following report:

REPORT OF THE SECRETARY AND TREASURER

RECEIPTS

Active membership dues	$2,425 00	
Associate membership dues	1,320 00	
		$3,745 00
Sale of Report of Twentieth Convention	$275 00	
Sale of badges	107 00	
Sale of publications	49 50	
Advertisements in proceedings	180 00	
Special fund (municipal statistics)	1,500 00	
		2,111 50
Total receipts		$5,856 50
Balance in bank January 1, 1897	$1,446 23	
Debtor to petty cash	60 29	
		1,385 94
		$7,242 44

DISBURSEMENTS

Salary of Secretary	$1,500 00	
Rent	420 00	
Testimonial	30 00	
Stenography and typewriting (including report of twentieth convention)	1,097 95	
Printing and stationery (including proceedings and papers read at meeting)	754 70	
Postage and telegrams	160 97	
Traveling expenses	373 77	
Sundry expenses	14 97	
Badges	133 80	
Furniture	8 75	
Committee on data	200 00	
Municipal statistics	1,400 00	
		6,094 91
Balance January 1, 1898		$1,147 53

Balance in bank January 1, 1898	$1,136 83	
Balance in petty cash January 1, 1898	10 70	
		$1,147 53

ASSETS

Cash as above statement	$1,147 53
Cash in hands of finance committee	915 97
Office furniture, as appraised by finance committee	267 00
Accounts receivable	635 00
	$2,955 50

LIABILITIES

Bill of James Kempster Printing Company	808 77
Net assets	$2,146 73

Respectfully submitted,

GEO. F. PORTER,
Secretary and Treasurer.

Approved September 23, 1898.
H. H. FAIRBANKS,
W. S. BARSTOW,
Finance Committee.

MR. STETSON: Has the report of the treasurer been audited?

THE PRESIDENT: No; because none of the members of the auditing committee are here.

MR. STETSON: I move that the report of the secretary and treasurer be accepted upon its approval by the finance committee, and spread upon the records; further, that the finance committee be requested to turn into the general bank account of the association the sum of $915.97, shown on the report of the secretary and treasurer, and also a further sum of $472.91, which they have in hand as the proceeds of the Montreal exhibition.

This motion was carried.

COMMITTEE ON LEGISLATIVE POLICY

THE PRESIDENT: You may remember that at our last executive session a motion was passed that a committee of five on legislative policy be appointed by the chair, with the chair as chairman of the committee. I will appoint the committee to consist of the following members:

SAMUEL INSULL, Chicago, Chairman
H. M. ATKINSON, Atlanta, Georgia
SAMUEL SCOVIL, Cleveland, Ohio
ERNEST H. DAVIS, Williamsport, Pennsylvania
CHARLES R. HUNTLEY, Buffalo, New York

REPORT OF THE EXECUTIVE COMMITTEE

THE PRESIDENT: The next report is that of the executive committee. The executive committee have had only one meeting during the year. The matter that the executive committee was called to discuss was the subject that we discussed in executive session the day before yesterday, namely, the question of the legislative policy of the association. I have no formal report to make, and will, therefore, call for the report of the committee on nominations, as the election of officers is the next business in order.

REPORT OF THE NOMINATING COMMITTEE AND ELECTION OF OFFICERS

Mr. Robertson presented the following report:

CHICAGO, June 9th, 1898.

National Electric Light Association,

GENTLEMEN: Your committee, to whom was referred the matter of nominating officers of this association and members of the executive committee to be elected at this meeting, begs to offer the following nominations:

For president, A. M. Young, Waterbury, Connecticut.

For first vice-president, E. W. Rollins, Denver, Colorado.

For second vice-president, F. A. Gilbert, Boston, Massachusetts.

For members of the executive committee, Samuel Insull, Chicago, Illinois; Samuel Scovil, Cleveland, Ohio; H. M. Atkinson, Atlanta, Georgia; F. A. Copeland, La Crosse, Wisconsin.

Respectfully submitted,

A. M. ROBERTSON,
JAMES I. AYER,
JAMES R. DEE,
Committee.

MR. HUNTLEY: I move that the report of the nominating committee be accepted, and that the secretary cast the ballot of the association for the gentlemen named.

Carried.

The secretary cast the ballot, and the president declared the gentlemen duly elected.

THE PRESIDENT: I am sorry that none of the officers elected are here to acknowledge their election. Speaking for Mr. Young and Mr. Gilbert, I assure you that they were very much disappointed at not being able to be present, and nothing but the most pressing business in connection with the large business interests with which they are charged, kept them away. They wished me especially to inform the association to that effect. It is a great pleasure to me personally to see another western man elected among the officers of the association. I take a great personal interest in the association, and I know that much can be done in the future by having an admixture of eastern, western and southern men on our staff of officers and executive committee.

So far as I am personally concerned, I wish to thank you all for what you have done toward making this convention the success it is universally conceded to have been. I am gratified that such a meeting should have taken place in the city in which I reside. I hope to do all I can in the future to carry this association to still further success.

Mr. Atkinson: There is one thing that I think we can hardly adjourn without doing—I am not going to make any lengthy speech, but the company in which I am interested has been a member of this association for quite a number of years, and I have, unfortunately, not been able to see my way clear to come to a previous convention; we have always been represented, however. I got up to say that, judging by this, my first convention, I am extremely sorry I did not begin to come sooner. I have been very much interested, and have learned a great deal, and I have an earnest feeling that this convention has been a great success; in my opinion it could have hardly have been a greater success. It has been a very business-like convention in every way. I want to express as earnestly as I can what strong feeling I have for the work; it is important work, and we can hardly put too much enthusiasm into it, and it is going to be of untold good for every member. In closing I will say that I think a large part of the success of this meeting is due to the enthusiasm and zeal and hard work that our president has put into it; and I want to move that a vote of thanks be extended to him for this work, and I will put that motion if it is seconded.

MR. ARMSTRONG: In seconding the motion I want to say I have been at every convention since February, 1890. I have not known a convention that attended more strictly to business; and, so far as I am able to judge, I have not seen a programme at any of our conventions so helpful as the one at this convention. I was opposed to the convention's coming to Chicago; I didn't want to come here at all. I am very glad to acknowledge that I was mistaken, and to be able to bear tribute, as Mr. Atkinson says, to the enthusiasm with which the president has seen to the preparation of the programme, and has seen to the execution of the programme when prepared. We certainly do owe him, as a convention, a great deal, and so far as I am concerned I hope it may be understood that this is not a mere formal vote of thanks, but a heartfelt vote of thanks for what he has done in the interest of the National Electric Light Association. I am perfectly willing, in other words, to let it go that this shall be a sample meeting for those that have not attended any of our other meetings.

MR. ATKINSON: It has been moved and seconded that the earnest thanks of this association be returned to our retiring president, Mr. Samuel Insull.

The motion was unanimously carried.

THE PRESIDENT: Gentlemen, the best way in which you can show your thanks for what little effort I have been able to put forth in connection with this convention is to attend the next one and give it the same class of support that has been given this one this week. It is all very well to give your retiring president a vote of thanks; but I will say this on behalf of my successor, that the best way in which you can show your appreciation of his work is to contribute to the programme of the next convention. The hardest work I had in connection with this convention was to get gentlemen to write papers. I think we were fortunate in finally getting a set of papers that will form a classic in this industry. I think our coming book will be of great use to all of us in our central-station work. Before next year, those of you that have been here through this meeting and have profited by the papers read and the discussions that followed—if you will only take a hand at it and write some papers yourselves, so that the rest of us can profit by what you have to say in regard to the various problems connected with our industry, you will be showing an appreciation of the efforts of the officials of this association that will please them very much. I thank you for the kind way in which you have expressed yourselves; and in dropping into the ranks of the association I shall try to do my share toward making the association a success.

MR. AYER: I move that the thanks of the meeting be extended to the Chicago Edison Company, the Metropolitan West Side Elevated Railroad Company, the South Side Elevated Railroad Company, the Northern Steamship Company, the Chicago Telephone Company, the American Telephone and Telegraph Company, and all others that have extended courtesies to the convention, for their kindness in so doing.

Carried.

MR. COPELAND: Mr. President, as I came into the room a few minutes since, I heard my name mentioned as having been placed on the executive committee. I do not know whether this action is diplomacy on the part of the association or not. A new member, not in the electrical business, but in the National Electric Light Association, I visited you last year at Niagara Falls as a guest, and now I am a full-fledged member and an active member in the Northwest. I do not think a man can learn too much in any of these associations. The field is large. Our little Northwestern association is coming along, and we hope some day to be on a par with you. We are doing a little smaller business than most of you people are; but I thank the association for putting me on the committee, and I will do what I can up in our country to swell the ranks and further the interests of this association.

MR. SCOVIL: I have a resolution that I desire to submit to the executive committee, and upon which I wish the sense of the meeting taken:

Resolved: 1st—That the purchase of existing plants by syndicates, for the purpose of recapitalizing them at fictitious values, is reprehensible.

2d—That the interests of users, taxpayers and bona-fide investors, demand that prices for services shall be limited by cost of operation plus a reasonable dividend upon the capital necessarily invested in construction and operation.

In moving this resolution, I simply wish to express my conviction that there is no one thing that is doing our interests more harm than what is being done by a set of people outside of us, who go into certain cities and find properties that have been conservatively managed, with an earning capacity that will stand more capital. They buy the properties and recapitalize them, and present a long series of figures showing that in a series of years, if the user will stand the watering, it will be a good property to invest in. I think it would do no harm if the association were to put itself upon record in this way and let the resolution be put to vote.

The resolution was seconded by Mr. Huntley and Mr. Field.

MR. BURLEIGH: I ask what is hoped to be the result of this resolution? Is it to be published to the world that we regard that practice as reprehensible, and that we do not engage in it?

MR. SCOVIL: That would certainly be my idea. We have had read at this meeting a paper which said that we were only entitled to a return upon the actual cost to duplicate our plant; and I took some exception to that, because I think that the trouble people have been put to in the past is entitled to some consideration. I feel, as I said before, that this method of doing things is very harmful.

MR. ARMSTRONG: Would it not answer the purpose to have this referred to the special committee that has kindred matters under consideration, and let it go to them for action. I move that it be referred to the committee.

THE PRESIDENT: Would you authorize the committee to publish that as the views of the association?

MR. ARMSTRONG: They could not do that until they reported to the association. This would be an unfinished matter, and would come up with their report next year.

The president put Mr. Armstrong's motion to refer the resolution, which was adopted.

MR. FIELD: I move a vote of thanks to the reception committee for their very considerate attention to the ladies accompanying the delegates to the convention.

Carried.

MR. HUNTLEY: I have in mind a man who has done as much, and more, perhaps, than any other individual connected with the association. Each year he has contributed to the pleasure, entertainment and comfort of all the members. As a recognition of his services, I move that Mr. Cyrus O. Baker, Jr., be elected an honorary member of the National Electric Light Association. I do not know that I need say more; he is known to us all, and his work has been appreciated by each and every one of us.

Mr. Ayer seconded the motion, and Mr. Baker was duly elected an honorary member.

The meeting then adjourned.

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